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SYNTHETICS AND SUBSTITUTES FOR AGRICULTURAL PRODUCTS

A COMPENDIUM

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MISCELLANEOUS PUBLICATION NO. 1141
ECONOMIC RESEARCH SERVICE
U.S. DEPARTMENT OF AGRICULTURE

PREFACE

Agricultural materials have been losing ground to synthetic materials in industrial, feed, fiber, and food markets. In recent years, the technological pace has quickened in the food industry with the development of synthetic food flavoring and coloring agents, the ability to synthesize most of the important amino acid groups, and other technological breakthroughs. These advances permit food processors to produce synthetic foods approaching natural foods in quality and cost. Similar advancements have taken place in industrial, feed, and fiber markets. Synthetic animal feeds and leather substitutes are examples of recent technical advances. Such developments have accentuated the need for an overall assessment of the future for agricultural materials.

A task force committee was established in the Marketing Economics Division of the Economic Research Service in the spring of 1968 to evaluate the current situation of substitutes in selected agricultural commodity markets. Members of this committee were William S. Hoofnagle, Chairman; Philip B. Dwoskin, Ray S. Corkern, Loyd C. Martin, Roy A. Ballinger, and Herbert H. Moede. The committee agreed to study the following markets: (1) fibers, (2) cereal grains, (3) dairy products, (4) animal products, (5) oil and oilseed products, (6) sweeteners, and (7) citrus.

The task of preparing the individual commodity reports was assigned to commodity specialists in the Marketing Economics Division. Authors were requested to include material in their chapters about possible production and marketing adjustments required to meet the challenge of substitutes.

The materials were assembled, reworked, and put into publication form mainly through the efforts of Ray S. Corkern and Philip B. Dwoskin.

Washington, D.C. 20250 April 1969

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SYNTHETICS AND SUBSTITUTES FOR AGRICULTURAL PRODUCTS

A Compendium

By Marketing Economics Division, Economic Research Service

INTRODUCTION

Industrial producers have long viewed agricultural markets as a vast untapped outlet for their products. Producers of synthetic products have successfully penetrated some agricultural markets. In others, their success has been limited. Currently, they are devoting an increasing amount of their research, development, and promotional resources toward increased penetration of agricultural markets.

Agricultural producers, processors, and marketers are becoming increasingly concerned about the replacement of agricultural raw materials and products by synthetics. They are adjusting to this emerging market situation by altering their production patterns, processing methods, and marketing strategies.

The Nature of Agricultural Product Substitutes

Agricultural product substitutes may be classified as (1) raw materials or products derived from nonagricultural sources and (2) agricultural raw materials or products that replace other agricultural products in their traditional or usual uses. Urea, noncellulosic fibers, saccharin, and cyclamates are examples of products derived from nonagricultural materials. Substitute materials from agricultural sources are usually used in the manufacturing of food and nonfood products that have the same general function, texture, and taste as traditional agricultural products. Filled milk, coffee whiteners, and meat analogs are examples.

Forces Affecting the Market for Agricultural Products, Synthetics, and Substitutes

Similar economic, technical, social, and institutional forces affect markets for agricultural product substitutes. The interaction of these underlying forces has established a marketing environment in which change is the key element. Personal disposable incomes are increasing. Industrial activity is at a high level. Shifts in market demand to better qualities, wider varieties of products, and added services are occurring. The state of the technical arts continues to open new possibilities for supplying products from alternate raw material sources and with attributes designed to satisfy new consumer wants and desires. Living, working, and consumption patterns are being altered and consumer protection legislation is receiving increasing emphasis. These types of changes in the marketing environment result in more processing and product diversification between producers and consumers and further open agricultural markets to potential substitutes. Agricultural producers, processors, and marketers, in most commodity areas, have been able to increase sales--mostly because of population increases--but have not been able to maintain their share of the market in a changing environment.

An accurate measurement of the total effect of synthetic agricultural substitutes on agricultural production, processing, marketing, and utilization is not available. The lack of such a measurement is due to the complexity of the economic and technical relationships that influence the production, marketing, pricing, and consumption of each farm commodity. However, some insights on specific agricultural products and markets can be gained from an analysis of emerging trends in production, market growth rates and shares, volumes marketed, and changes in end-use patterns. Such analytic techniques were employed in the individual chapters of this report.

Furthermore, an appraisal of the individual commodity areas does provide a basis for judgment as to the total impact of agricultural substitutes on traditional

markets for agricultural products. One factor that cuts across the board for all agricultural products is the increasing affluence of our society. Given this situation, what inferences can be made concerning the potential effects of synthetic substitutes on agricultural production and marketing? A related question is, how can the agricultural sector best adjust to these changing conditions?

Consumer affluence creates a vast and increasing demand for greater variety and better quality products. In addition, improved technical capabilities provide a basis for the market expansion of present synthetic substitutes and open new opportunities for the development and commercial introduction of many new food and nonfood synthetic substitutes.

The effect of these synthetic substitutes on agricultural markets will vary depending on their sources of raw materials. New synthetic substitutes derived wholly from nonagricultural raw materials are likely to affect agricultural markets more adversely than those derived wholly or partially from agricultural raw materials. Substitutes derived from nonagricultural raw materials have made and can be expected to continue to make inroads in agriculture's markets, primarily in the nonfood markets. These types of substitutes may further alter agriculture's share of the market, reduce market volumes, and ultimately reduce the incomes of agricultural producers.

The current fiber and feed markets are examples of agricultural markets which have been affected by synthetics derived from nonagricultural sources. The domestic consumption of all fibers was 9.3 billion pounds in 1967, a 43 percent increase over the 1955 consumption. From 1955 to 1967, cotton consumption increased by 11 percent. If cotton consumption had increased at the same rate as total fiber consumption, then cotton consumption in 1967 would have been 5.5 billion pounds rather than the 4.7 billion pounds actually consumed. At the farm level, this represents a difference of approximately 1.6 million 500-pound bales or approximately $205 million of gross income. In the feed market, the use of urea in ruminant feeds is another example. In 1966, 192,000 tons of feed grade urea were fed to ruminants, the equivalent of 1.1 million tons of 44 percent soybean meal. This is equal to the soybean meal produced on approximately 1.9 million acres of soybeans or approximately $90 million at the wholesale level.

A somewhat different situation exists for substitutes derived wholly or partially from agricultural products. In this situation, substitutes may alter the traditional market relationships among the various agricultural commodities in both food and nonfood markets. Agriculture's share of the market and volumes marketed may not be reduced. However, in many cases incomes from marketing will be redistributed among the various agricultural commodity groups and producing regions. This could further result in a shift in the quantity and mix of farm production inputs used and alter the past comparative cost advantages of specialized commodity production regions. Another possible effect is that a major share of the commodity or product value will be added at the processor level rather than the farm production level. This may lead to widened spreads between farm producer prices and retail prices and further reduce the farmer's already dwindling share of the consumer's dollar.

Substitutes derived from agricultural raw materials may have their greatest impact in food markets due to increased demand for foods with "built-in" convenience properties, specialized functional attributes, and esthetic appeal. These properties are generated through added processing and substitution of one agricultural raw material for another. Some recent examples are synthetic milks made from vegetable oils and other nondairy ingredients, and meat-like products formulated from vegetable protein.

Future Prospects

The agricultural sector has been partially successful in adjusting to past inroads of synthetic and substitute materials. Successful adjustment to future inroads will depend on how well we read the emerging changes in technical, economic, and social forces. These forces are expected to shape and influence the future supply and demand for traditional agricultural commodities as well as for present and potential synthetics and substitutes. Insights into the general nature of some possible future changes can be gleaned from past trends and marketing experiences of the individual commodity areas. These are the basis for judgment of the future prospects for agricultural products in the following paragraphs.

1. The agricultural sector is likely to remain the major supplier of raw materials

for the food market. Traditional commodities utilized in this market, however, will undergo increasing amounts of processing before reaching the final consumer. This will probably intensify intercommodity competition as each farm commodity seeks to maintain or expand its proportionate share of the food market. Another possibility is that agriculture's share of the consumer food dollar will further decline as more product attributes are demanded and "added on" at the processor level.

2. Federal, State, and local food regulations will play an important role in the development and commercialization of new synthetic food products derived from nonagricultural sources. These products will be likely to have product attributes that cannot be obtained from agricultural products and will be produced for specific segments of the food market. In the past, Federal, State, and local regulations have prevented extensive penetration by these types of substitutes into agricultural food markets. However, it is likely that in the future, regulations will be used primarily to insure product quality and safety rather than to prevent the introduction of synthetics.

3. Although penetration of nonfood markets by synthetics will continue, it will be partially offset by continuing programs of research on agricultural commodities. Producers for agriculture's nonfood markets have been partially successful in adjusting to substitutes by developing new derivatives and by actively seeking alternative markets for displaced agricultural raw materials. Research in new uses for agricultural products and improvement in processing technology will play a key role in maintaining present nonfood markets and developing others.

4. Agricultural producers, processors, and marketers, as well as Government units, will continue to search for new strategies to meet the competition from synthetics. If new strategies are to be successful, they must reflect consumers' desires and expectations. The technical and research capabilities are available to meet this challenge.

Manmade Substitutes in the Fibers Market

By Ray S. Corkern and Cleveland Eley

CURRENT SITUATION

Fibers are classed as natural or manmade. The manmade fibers are further classified as manmade cellulosics or noncellulosics. The manmade cellulosics are rayon, rayon acetates, and triacetates; they are manufactured from cellulose derived from pulpwood. Manmade noncellulosics are designated by generic names (nylon, olefin, polyester, acrylic, etc.) that specify their basic structure and composition. A brief summary of manmade cellulosics and noncellulosics, their principal raw materials and major end-uses, is shown in table 1. Each of these fibers competes with cotton and wool for a share of the U.S. fiber market.

Annual Growth Rates

Annual growth rates in consumption of fibers from 1949 to 1966 in the United States are presented in tables 2 and 3. The annual growth rate for all fibers was 2.7 percent; however, the annual growth rate for individual fiber types ranged from -0.8 for wool to 19.6 percent for manmade noncellulosics. This would indicate that market expansion rates that are greater than 2.7 percent for individual fibers are at the expense of market shares for other fibers. The relatively large growth rate for manmade fibers indicates they are replacing some of the natural fibers as well as taking most of the increase in the aggregate market.

The growth rates by end-use ranged from 33.2 to -11.9 percent (table 3). Manmade noncellulosics had a positive growth rate in all end-uses.

Domestic Consumption and Market Share

Changes that have occurred in average domestic consumption and market share are summarized in table 4. Each type of fiber except wool shows an increase in average use from 1955 to 1967. However, only manmade noncellulosics show an increase in their market share. Market shares of cotton, wool, and rayon have declined.

The per capita consumption of all fibers increased from 39.4 pounds in 1955 to 46.9 pounds in 1967. This gain was not equally shared by the different types of fibers. For example, the per capita consumption of cotton, wool, and rayon declined; cotton from 25.4 to 23.5 pounds, wool from 3.0 to 2.1 pounds, and rayon from 8.4 to 7.6 pounds. In contrast, consumption of manmade noncellulosics rose from 2.6 to 13.7 pounds per capita over the 13-year period.

Another way to express the magnitude of cotton and wool market "losses" is as a changing percentage of the per capita consumption of all fibers. Cotton and wool had 72.1 percent of the per capita consumption in 1955 but only 54.6 percent in 1967, whereas noncellulosics went from 6.6 percent in 1955 to 29.1 percent in 1967.

U.S. and Foreign Production

World production of textile fibers is trending upward (table 5). Between 1955 and 1967 the world production of all fibers increased by 34.6 percent, although U.S. production decreased by 18.2 percent. Also, the percentage increase in foreign production of fibers shown in table 5 was greater than the increase in U.S. production. For example, foreign production of cotton increased by 36.5 percent while U.S. production decreased by 49.4 percent. This has altered the production share of the United States. In 1955 the United States produced 29.1 percent of the world textile fibers, but in 1967 the U.S. share dropped to 17.7 percent.

The percentage declines for U.S. production of cotton and total fibers were primarily due to low cotton production in 1967. Weather was unfavorable in that year, and cotton production was a little

Table 1.--Selected types of manmade fibers, principal raw materials, and end-uses, 1967

Generic names and important subgroups	Principal intermediate raw material	Source of raw material	Major textile end-uses
Nylon:			
Nylon 6.....	Caprolactam	Petroleum	Carpets, apparel, tire cord
Nylon 6/6.....	Hexamethylene diamine, adipic acid	Petroleum	Carpets, apparel, and industrial products
Nylon 6/10.....	Hexamethylene diamine, sebacic acid	Petroleum and castor oil	Industrial products
Nylon 11.....	11-Amino undecanoic acid	Castor oil	Industrial products
Polyester.....	Dihydric alcohols and terephthalic acid	Petroleum	Wash-and-wear apparel, home furnishings, tire cord
Acrylic.....	Acrylonitrile	Petroleum	Carpets, women's knit wear
Modacrylic.....	Acrylonitrile	Petroleum	High pile fabrics
Rayon:			
Viscose rayon	Purified cellulose	Cotton linters, pulpwood	Home furnishings, apparel, tire cord
Cuprammonium	Purified cellulose	Cotton linters, pulpwood	Women's lightweight apparel
Saponified	Cellulose and cellulose acetate	Cotton linters, pulpwood	Lightweight fabrics
Acetates.....	Cellulose acetates	Cotton linters, pulpwood, and acetic acid	Apparel
Triacetates.....	Cellulose acetates	Cotton linters, pulpwood, and acetic acid	Outerwear fabric, wash-and-wear
Olefin.....	Propylene and ethylene gas, other olefins	Petroleum	Carpeting, industrial products
Spandex.....	Polyurethane	Petroleum	Swimwear, hosiery, outer wear apparel, foundation garments
Saran.....	Vinylidene chloride	Petroleum	Upholstery, outdoor furniture, industrial products
Metallic.....	Aluminum, steel	Metals	Decorative purposes, draperies
Glass.....	Glass	Silica, sand, and others	Home furnishings and industrial products
Rubber.....	Natural and synthetic rubber	Natural rubber and petroleum	Webbing, foundation garments, surgical
Vinyon.....	Vinyl chloride	Petroleum	Industrial products

Table 2.--Average annual change and growth rate, fiber consumption by type of fiber, United States, 1949-66

Type of fiber	Average annual change	Annual growth rate
	Mil. lb.	Percent
Cotton	46.6	1.1
Wool	-5.7	-.8
Rayon and acetate	31.1	1.8
Manmade noncellulosics[1]	125.3	19.6
Total all fibers	199.8	2.7

[1] Does not include glass or metallic fibers.

Source: Computed from data in Textile Organon. Textile Econ. Bur., Inc. Monthly.

Table 3.--Annual growth rate, fiber consumption by end-uses, United States, 1949-66

End-use	Cotton	Wool	Manmade fibers		All fibers
			Rayon and acetate	Manmade noncellulosics[1]	
	- - - - - - - - Percent - - - - - - - -				
Men's and boys' wear	2.5	-1.2	-2.2	22.2	2.7
Women's, misses', children's, and infants' wear	1.3	1.1	.1	14.7	2.6
Home furnishings	2.3	-1.4	10.0	33.2	4.9
Other consumer products	.3	-.1	4.7	29.5	2.6
Industrial use	-3.1	-11.9	-2.4	17.0	.1
All uses	1.1	-.8	1.8	19.6	2.7

[1] Does not include glass or metallic fibers.

Source: Computed from data in Textile Organon.

Table 4.--Domestic consumption and market share of fibers, 1955 and 1967[1]

Type of fiber	Consumption		Change 1955-67	Market share	
	1955	1967[2]		1955	1967[2]
	Mil. lb.	Mil. lb.	Percent	Percent	Percent
Cotton	4,207	4,671	+11	64	50
Wool	490	424	-13	8	5
Rayon and acetate	1,395	1,520	+9	21	16
Manmade noncellulosics	426	2,719	+538	7	29
Total fibers	6,517	9,334	+43	100	100

[1] Domestic consumption is mill consumption plus raw fiber equivalent of imported textile manufactures, less raw fiber equivalent of exported textile manufactures. Does not include glass fibers, mohair, silk, or vegetable fibers such as jute and flax.
[2] Preliminary.

Source: Supplement for 1966 to Statistics on Cotton and Related Data 1925-1962. U.S. Dept. Agr., Statis. Bul. 329, 1967.

Table 5.--Production of selected fibers, United States and foreign, 1955 and 1967

Fiber	1955		1967[1]		Change	
	U.S.	Foreign	U.S.	Foreign	U.S.	Foreign
	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Percent	Percent
Raw cotton	7,361	14,480	3,725	19,770	[2] -49.4	+36.5
Raw wool	283	4,402	211	5,787	-25.5	+31.5
Rayon and acetate	1,261	3,763	1,388	[3] 5,788	10.0	+53.8
Manmade noncellulosics[4]	455	215	2,643	[3] 4,372	481.0	1,933.5
Total	9,360	22,860	[2] 7,658	35,717	[2] -18.2	+56.2
World	32,220		43,375		+34.6	

[1] Preliminary.
[2] These values are atypical. In 1967, U.S. cotton production was one-half the 1955 production due to the diversion and extremely unfavorable weather.
[3] Estimated, based on growth from 1965 to 1966.
[4] Does not include glass or metallic fibers.

Sources: Supplement for 1966 to Statistics on Cotton and Related Data 1925-1962. U.S. Dept. Agr., Statis. Bul. 329, 1967. Also; Supplement for 1965 to Wool Statistics and Related Data 1920-1964. U.S. Dept. Agr., Statis. Bul. 363, 1966.

less than one-half the 1955 volume. In comparison, from 1955 to 1965 there were increases in U.S. cotton and total fiber production of 1.7 and 20.7 percent respectively.

Manmade fiber production capacities increased in the U.S. between 1955 and 1967, but they increased even more in foreign countries (table 6). Manmade fiber growth in foreign countries takes a share of the textile market overseas.

U.S. Trade Balance of Manufactured Textiles and Textile Fibers

The U.S. trade balance of manufactured textiles and textile fibers has been favorable in terms of physical quantity since 1955 due to large exports of cotton fiber (table 7). However, the trade balance in cotton manufactured textiles has been unfavorable since 1960 and is becoming more unfavorable. Wool imports exceed exports in both manufactured textiles and raw fiber primarily due to declining U.S. production. Imports of manmade fibers have been greater than imports of manufactured manmade textiles. Imports of rayon and acetate fibers averaged around 100 million pounds per year in 1962-67, but imports of noncellulosic fiber increased from 21 million pounds in 1962 to 80 million pounds in 1967.

The U.S. trade balance in terms of value is shown in table 8. The trade balance of raw fiber has been favorable, whereas the balance of manufactured products shows a counter trend. Since 1962, only 1 year has shown a small positive trade balance for fibers and textiles.

Domestic Manmade Fiber Production Capacity and Shipments

Since the early 1960's, producing capacity for noncellulosic fibers in the United States has expanded rapidly (table 9). From 1961 to 1967, the production capacity for noncellulosics expanded threefold, from 1.1 to 3.2 billion pounds, and industry sources estimate that capacity will reach 4.2 billion pounds by 1969. Manmade cellulosic capacity expanded from 1.4 to 1.8 billion pounds from 1961 to 1967. However, capacity to produce the various individual types of noncellulosic fiber has not expanded at the same rate.

Estimates of manmade noncellulosic fiber shipments to domestic mills provide a better insight into changes that are occurring in the noncellulosic fibers market (table 10). In 1955, only limited data were available

Table 6.--Manmade fiber producing capacity, United States and world, selected years

Fiber	1955	1965	1967	Change 1955-65	Change 1965-67
	Mil. lb.	Mil. lb.	Mil. lb.	Percent	Percent
Manmade noncellulosic:					
United States	512	[1] 2,101	[1] 3,180	243.3	51.4
Others	253	[2] 3,085	5,115	1,118.2	65.8
World	865	5,186	8,295	499.5	60.0
Rayon and acetate:					
United States	1,713	[3] 1,729	1,767	.9	2.2
Others	4,109	[3] 6,818	7,023	66.0	3.0
World	5,822	[3] 8,547	8,790	46.8	2.8

[1] As of November.
[2] As of March.
[3] As of July.

Source: Textile Organon.

Table 7.--U.S. trade balances in textiles (fiber equivalent) and raw fiber, selected years

Year	Cotton	Wool	Manmade fibers: Rayon and acetate	Manmade fibers: Noncellulosic	Total
	1,000 pounds				
Textiles:[1]					
1955	175,841	-75,885	80,768		180,724
1965	-186,792	-140,464	56,984		-270,272
1966	-317,373	-130,169	25,131		-422,411
1967[2]	-250,044	-111,114	1,236		-359,922
Raw fibers:					
1955	1,153,100	-248,461	-157,200	2,700	750,139
1965	1,831,900	-270,963	-53,500	-41,900	1,465,537
1966	1,736,800	-277,076	-93,900	-65,600	1,300,224
1967[2]	1,895,100	-187,171	-70,200	-72,200	1,565,529
Textiles and raw fibers:[1]					
1955	1,328,941	-324,346	-73,732		930,863
1965	1,645,108	-411,427	-38,416		1,195,265
1966	1,419,427	-407,245	-134,369		877,813
1967[2]	1,645,056	-298,285	-141,164		1,205,607

[1] Separate data for cellulosic and noncellulosic fibers not available. A minus sign represents years in which imports exceed exports.
[2] Preliminary.

Source: Textiles and Apparel. U.S. Tariff Comn., TC Pub. 226, Jan. 1968.

Table 8.--Value of U.S. imports, exports, and trade balance of textiles and textile fibers, 1962-67

Year	Manufactured[1]			Raw fibers	Total textiles and raw fibers[1]
	Yarns, fabrics except clothing	Clothing	Total		
	-Million dollars-				
Imports:					
1962.....	654	363	1,016	327	1,344
1963.....	679	393	1,072	356	1,429
1964.....	683	450	1,133	338	1,472
1965.....	795	537	1,332	376	1,709
1966.....	901	599	1,500	380	1,880
Jan.-Sept. 1967	607	484	1,091	202	1,293
Exports:					
1962.....	494	85	579	663	1,242
1963.....	491	90	581	721	1,303
1964.....	582	98	680	829	1,509
1965.....	528	140	668	616	1,284
1966.....	554	160	715	564	1,279
Jan.-Sept. 1967	392	120	512	459	971
Trade balance:					
1962.....	-160	-278	-437	335	-102
1963.....	-188	-303	-492	365	-127
1964.....	-102	-352	-454	491	37
1965.....	-267	-397	-664	240	-424
1966.....	-347	-439	-786	185	-601
Jan.-Sept. 1967	-215	-364	-579	257	-323

[1] A minus sign represents an excess of imports over exports.

Source: Textiles and Apparel. U.S. Tariff Comn., TC Pub. 226, Jan. 1968.

Table 9.--Manmade fiber production capacity, United States, selected years

Fiber	1961	1965	1967	1969 estimate
	-Million pounds-			
Nylon.....	594	1,049	1,341	1,580
Olefin.....	47	98	199	333
Polyester.....	([1])	([1])	1,011	1,484
Acrylic and modacrylic.....	215	446	538	645
Others noncellulosics.....	207	508	91	152
Manmade cellulosics.....	1,421	1,729	1,767	([2])
Total.....	2,484	3,830	4,947	[3] 4,194

[1] Included in "other" category.
[2] Not available.
[3] Does not include an estimate for manmade cellulosics.

Source: Textile Organon.

Table 10.--Manmade fiber shipments to domestic mills, selected years

Type of fiber	1955	1965	1967
	- -Million pounds- -		
Nylon	231	861	907
Olefin	([1])	60	115
Acrylic and modacrylic	55	325	371
Polyester	([1])	290	537
Other noncellulosics	69	91	185
Glass	77	268	303
Manmade cellulosics	1,246	1,466	1,408

[1] Included in "others" category.

Source: Textile Organon.

on manmade noncellulosic fiber shipments by types. The two most recent years for which estimates are available, 1965 and 1967, show the increasing growth in use of olefin and polyester fibers. Olefin fibers are mostly used in industrial products and in carpets, whereas polyesters find increasing outlets in those same products in which cotton is extensively used, such as shirts and bedsheets.

COMPETITIVE SITUATION

Major factors affecting the competitive relationships between natural and synthetic fibers are (1) changing consumer incomes, (2) prices, (3) research and development of new products, (4) changing market structures, and (5) marketing techniques.

The aggregate demand for fiber and fiber products is closely related to both the level of and year-to-year changes in per capita personal disposable incomes, textile product prices, and the deviation from norm of stocks of cotton cloth compared with unfilled orders. Elasticities for these factors have been reported as +0.78, +1.00, -0.23, and -0.07, respectively; they represent the percentage change in per capita domestic fiber consumption associated with a 1-percent increase in the individual factors when all other factors are held constant.[1] Although annual increases in the aggregate demand for fibers are relatively small, annual shifts between the natural and manmade fibers do occur. Interfiber shifts may be temporary, such as those due to changes in apparel styles, or they may be longer lasting. An interfiber shift is usually associated with a technical improvement that enhances the functional properties of the substitute fiber. This is assuming there is no change in the pricing structure of the competing fibers.

Prices

Prices for selected manmade fibers, cotton, and wool are shown in table 11. These prices are averages and do not reflect all possible price differentials that may exist for fibers having specific physical or functional characteristics. Between 1960 and 1967, prices declined for all fibers except one grade of rayon. Although most fiber prices have declined, there may exist some control over the pricing pattern. In the case of manmade fibers, sellers offer inventory price adjustment schemes, price schedules reflecting promotional allowances, and volume discounts. Government marketing and production programs influence the pricing pattern for the natural fibers. However, in each case differential pricing is used to reflect differences in physical characteristics such as staple length, denier, and fineness or diameter.[2]

New Product Development

New chemical compositions for manmade fibers and fiber products have taken two forms. The first is the development of new fibers having distinctive structural and compositional characteristics, and the second is chemical modification of the physical characteristics of the fiber without altering the fiber's basic composition. Only the second form of development is available to natural fiber processors. For example, the basic composition of cotton or wool cannot be altered to form new fibers. However, it is possible to modify the natural characteristics by some chemical or physical process, or to breed improved properties into cotton and wool at the farm level.

Manmade fiber producers have a greater economic incentive to develop new fibers and fiber products because of the protection that arises from the patent system. The manmade fiber producer can patent the basic fiber composition plus any modifications that he can develop. Chemicals

[1] James R. Donald, Frank Lowenstein, and Martin S. Simon. The Demand for Textile Fibers in the United States. U.S. Dept. Agr., Tech. Bul. 1301, 1963.

[2] A denier is a measure of fiber fineness and density. A 1-denier yarn weighs 1 gram per 9,000 meters of length, a 3-denier yarn weighs 3 grams per 9,000 meters, etc.

Table 11.--Prices per pound of selected manmade and natural fibers, selected years[1]

Fiber	1960	1965	1967	Change 1960-67
	Cents	Cents	Cents	Percent
Rayon staple fiber, viscose 1 1/2 denier	29.9	28.0	28.0	-6.4
Acetate staple fiber, 5 denier	36.0	40.0	40.0	+11.1
Nylon staple and tow, 3 and 6 denier, and semidull, normal tenacity, not crimpset	128.0	103.5	96.0	-25.0
Nylon staple and tow, 3 and 6 denier, bright and semidull, normal tenacity, crimpset	130.0	105.5	98.0	-24.6
Nylon staple and tow, 15 denier, normal tenacity, not crimpset, 1st grade	108.0	88.0	77.0	-28.7
Acrylic staple and tow, 3 denier, bright and semidull	128.2	106.0	104.6	-18.4
Acrylic staple and tow, 3 and 5 denier, bright and semidull	118.0	110.0	110.0	-6.8
Acrylic staple fiber, 15 denier, bright and semidull regular	93.0	74.5	66.8	-28.2
Acrylic staple fiber, 2 and 3 denier, dull and bright	102.0	78.0	78.0	-23.5
Modacrylic staple fiber natural color, 3, 6, and 12 denier	110.0	75.0	75.0	-31.8
Polyester staple and tow, 3 denier	136.0	85.2	65.0	-52.2
Polyester staple fiber, 3 and 4.5 denier	140.7	85.2	70.0	-50.2
Cotton, American upland middling 1 inch	[2] 30.9	[3] 29.6	[5] 24.6	-20.4
Wool, average wholesale price, four grades, Boston[4]	113.0	120.0	[5] 106.5	-5.8

[1] Prices for manmade fiber are list prices which are subject to discounts particularly if sold on an unbranded basis or if the market is soft.
[2] 15-market average.
[3] 14-market average.
[4] Prices paid to U.S. producers are considerably lower than these prices.
[5] Preliminary.

Sources: Agricultural Statistics, 1967. U.S. Dept. Agr. Supplement for 1966 to Statistics on Cotton and Related Data 1952-1962. U.S. Dept. Agr., Statis. Bul. 329, 1967. Supplement for 1965 to Wool Statistics and Related Data 1920-1964. U.S. Dept. Agr., Statis. Bul. 363, 1966.

added to cotton and wool can modify their physical characteristics, but their basic compositions remain the same. Examples are the crosslinking of cotton to produce durable-press garments and the application of compounds to cotton which cause it to resist soiling. These developments have been subject of many patents. Also, the patent system does provide cotton breeders an economic incentive for the development of new varieties.

The introduction of new or modified fibers and fiber products may continue to be one of the methods used by manmade fiber producers to gain a share of the fiber market. Also, the development of new strains and varieties and the modification of natural fibers will remain one of the major competitive tools to offset the inroads of manmade fibers.

Changing Market Structure

General changes in the structure of manmade fiber markets have increased both price and nonprice competition between natural and manmade fibers. For example, the entrance of new firms into manmade fiber production has been facilitated by the lapse of basic patents covering nylon and polyester fiber. To offset the price-depressing effects of the resulting new

supplies of manmade fibers, some manmade fiber producers have tended to integrate backward toward their basic raw material source. Joint ventures by manmade fiber producers and natural gas producers have occurred in the United States.

Competition due to increased supplies of manmade fibers is not limited to the domestic market. Manmade fiber production capacities in foreign countries are expanding. These supplies will enter the world market as fibers or finished textile products, although exporting countries will attempt to shift from exports of basic fibers to finished textile products. If the shift is accomplished, the major share of the value added by manufacturing will accrue to producers in the exporting country. However, the success of the shift will depend on world trade policies.

Another structural feature of the manmade fiber market is plant location. Plants for the production of monomers used in manmade fiber polymers are often located near their raw material source, and polymer and fiber-forming plants are located near textile plants. This structural feature lowers transportation cost. Monomers are shipped to polymer and fiber forming plants at petroleum byproduct rates, thus having minimum transportation cost. This situation also offers another competitive advantage. Manmade fiber polymer producers may own or lease the required tank car or tank truck transportation equipment. This equipment may also function as a storage unit at the receiving point, eliminating the usual demurrage charge as well as reducing fixed storage facility costs.

Marketing Techniques

The production patterns and marketing strategies of manmade fiber producers differ from those used by cotton and wool producers. The most apparent difference is that there are many producers of natural fibers, while manmade fiber production is concentrated in a relatively few firms. Therefore, output of manmade fiber can be adjusted quickly when market demand shifts. Output adjustments by natural fiber producers are relatively slow due to seasonal production patterns, year-to-year changes in the comparative advantage of other crops relative to cotton, geographical dispersion, and a larger number of marketing steps from producer to user. Also, market outlets for manmade fibers and other polymers are not limited to textile end-uses. Fiber polymers are used extensively in molded, extruded, and film forms in the plastic industry. Natural fibers are somewhat limited in their applicability to nontextile uses. However, some research is being conducted on new nontextile uses for cotton fiber.

Another competitive advantage that manmade fiber producers may have over natural fiber producers is their ability to differentiate their products and marshal resources with which to advertise and promote their products. Most manmade fibers are marketed under tradenames or brands, and consumers associate product quality with the producer's reputation. Consumer-oriented advertising and promotional programs with producer tradenames help tie producer, processor, and consumer markets together. The Cotton Research and Promotion Act of 1966 may accomplish the same effect for natural fibers.

Technology

Technical developments that influence fiber competition may be classified into four categories: (1) Development of different starting raw materials and intermediates for existing fibers (the shift over a period of years from ethyl alcohol to cyclohexane to make the diamine for nylon 66 is an example); (2) new types of fiber-forming polymers such as saran and spandex; (3) continuous processes to increase production speeds, such as continuous polymerization, continuous vat dyeing, and use of automatic gin balers; and (4) chemical and mechanical modifications for fibers such as soil resistance, fire retardance, and crimping. In the last decade, manmade fiber producers and textile manufacturers have made significant progress in each of the above categories. Over the same period, technical developments applicable to natural fibers were limited to categories (3) and (4).

Technical developments in manmade fibers often affect the use of natural fibers--for example, textile manufacturers utilize the improvements in a manmade fiber by blending it with one or more natural fibers. Differences in fineness, length, strength, color, hand, and many other fiber properties have long been dealt with through blending even by textile mills using all-cotton or all-wool raw materials. It is well known that the advent of manmade fibers greatly enhanced the ability

of textile manufacturers to resolve fiber and yarn blending problems.

Blends of fibers are used to attain specific qualities desired in end-use products. Not only quality characteristics but prices and processing costs influence the manufacturer's decision to use blends.

Because demands in end-use markets are the principal determinant of the use of blends, natural fiber suppliers need to keep themselves informed concerning end-use markets. Defensive action against the loss of entire outlets can be taken when such vulnerability is recognized. Opinion is strongly divided on the effects blends have on various market outlets. However, natural and manmade fibers still compete in various end-uses. This situation may be altered as technology and pricing patterns change in those end-use markets in which fibers are presently blended.

Natural and manmade fiber producers and textile manufacturers will continue to improve the physical and esthetic characteristics of their fibers and fiber products to better adapt them to consumer demands. In the case of manmade noncellulosic fibers, new ones may be developed or chemical and physical modifications may be made by grafting chemical subunits to the basic chemical molecules of the fibers. In natural fibers, technical innovations will continue to be limited to chemical and physical modifications. Improvements will be made in flame resistance, permanent press characteristics, soil resistance, ease-of-care characteristics, moisture absorption, and texture. In addition, new varieties of natural fibers may be developed as a result of public and private research.

Technical developments outside the present textile industry also affect the competitive environment for natural and manmade fibers. Nonwoven textile substitutes have been developed from synthetic resins such as polyvinyl chloride and urethane. These products will compete for a share of cotton's and wool's former uses in indoor and outdoor clothing, upholstery, and industrial products. Textile substitutes made of paper can satisfy users' wants for one-time-use apparel or draperies. A third development is the manufacture of fiber-grade cellulose from hardwood pulp that may expand the supply of raw materials for manufacturing manmade cellulosic fiber. These and other technical achievements will continue into the future.

Government Programs and Regulations

Government programs and regulations which affect interfiber competition in the fiber industry are farm programs, marketing programs, and consumer protective or regulatory programs.

The primary objective of the farm programs is to support producer incomes through a system of price and supply stabilization adjustments. Key elements of present cotton programs are price supports near world price levels, acreage restrictions, and incentive payments to farmers. These key elements in addition to export subsidies were included in previous cotton programs.

The wool program is slightly different from the cotton program. It includes an incentive payment made to producers to encourage production of more wool, but growers have not responded to achieve the goal.

Government marketing programs and regulations promote orderly marketing of fiber and fiber products. Some specific examples of these are (1) establishment of standards and grades for fiber, (2) labeling requirements, (3) commodity warehousing and exchange regulations, (4) support of cooperatives, (5) collection and dissemination of market news, (6) commodity production loans to growers, and (7) foreign trade and market development activities.

Some examples of consumer protective or regulatory programs that indirectly influence the fiber market are flame-retardance regulations, patents, and import regulations. These programs usually effect general changes in the market environment for the benefit of all consumers, rather than changes that benefit specific consumers, commodities, or producers.

ADJUSTMENTS NEEDED TO MEET COMPETITION

Public Research Programs

In the past, publicly financed research programs have concentrated on improving production efficiency through seed development, disease and pest control, fertilization, and harvesting technology. The primary objectives of these programs were to reduce production costs and to improve qualities and yield of natural fibers. These activities will continue to be a necessary part of future research programs in order

that farmers' returns from natural fibers will not be lost through competition from manmade fibers.

An extensive program of basic and applied research is being conducted at the U.S. Department of Agriculture's utilization laboratories. This research is designed to develop new uses for natural fibers, new processing techniques, and means of modifying natural fibers to meet current and potential market requirements. The research results of the utilization laboratories have played a key role in the maintenance of natural fiber markets.

Research programs on marketing are being conducted at the State and Federal levels. These programs have been strongly oriented toward solving temporary regional or local problems and explaining past market phenomena, rather than forecasting market changes that will influence consumption. For example, numerous studies have been made concerning the aggregate demand for natural fiber, but very few have been on the qualitative attributes of fibers from the standpoint of end-uses and their net effect on the aggregate demand for natural fibers. A partial explanation is that data are limited and interdisciplinary cooperation with other social sciences is lacking. Much more intensive and extensive market research is needed on the impact of increased purchasing power among age groups most sensitive to changing apparel fashions, and to the increased influence of end-use attributes that result in aggregate annual market demand shifts, such as cut, color, style, and design of apparel.

Other areas of the marketing system needing extensive research are transportation and storage patterns, optimum processing methods for improving natural fiber qualities, improvement of standards, and the effect of public programs on market structure, performance, and efficiency.

Textile Firms

Products of many textile firms favor the use of more than one type of fiber. Therefore, intrafirm adjustments may or may not improve the competitive position of natural fiber and fiber products. In general, these firms attempt to maintain or increase their profits rather than increase the usage of a single fiber. In this situation the improvement or maintenance of the competitive position of natural fiber will depend on the promotional, product development, and utilization research activities of natural fiber associations and public agencies. These research and development activities are designed to provide the fiber-using industry with a continuous flow of up-to-date technical and marketing information on natural fibers and fiber products.

Cooperatives and Farm Organizations

The competitive position of natural fibers may be enhanced by cooperatives and farm organizations. These organizations must continue to emphasize the lowering of farm production and marketing costs and seek favorable public policy determinations. They may also develop integrated purchasing and distribution systems that are adaptable to growers' products and to production inputs used by growers. They may seek to perform marketing functions now performed by other market intermediaries. Forward integration by cooperatives or farm organizations into marketing activities, if efficiently performed, could enhance the competitive position of natural fiber producers.

Trade Associations

Approximately 145 associations are active in the U.S. textile industry. These associations represent most segments of the industry and perform varied functions, such as promotion, research, data collection, and public relations. The impact of these associations on the competitive position of natural fibers has not been quantitatively determined.

Trade associations must develop cooperative agreements to pool their resources and efforts if they are to be effective in promoting natural fibers. This has been attempted in the past, but with limited success. The recent enactment of the Cotton Research and Promotion Act strengthened the financial support needed for promotional and research activities for cotton.

Production and Marketing Programs by Public Agencies

Government production and marketing programs have been a major element in the market for natural fibers. These programs are designed to (1) improve farm incomes and keep U.S. cotton competitively priced, (2) assure stable domestic

supplies, and (3) assure adequate supplies to meet U.S. world trade and foreign aid commitments. The success of these programs is highly dependent on the ability to anticipate future outputs and consumer demands. Output may change when yield-increasing technologies are adopted or when the weather varies, and demand shifts may occur due to rapidly increasing consumer incomes. Major efforts are needed to develop more precise methods for predicting results and administering the programs if such changes should occur.

SUMMARY

The market for natural and manmade cellulosic and noncellulosic fibers is changing. Natural fibers (cotton and wool) have experienced a decline in market share, a slight decline in per capita consumption, and a market growth rate that is less than the rate of growth of the total market. In addition, production and fiber-producing capacities are expanding at a greater rate in foreign countries than the United States. These changes are due to many interrelated factors, including the nature of natural and manmade fibers, technology, and a changing economic environment.

Some of the changes that are expected to affect the future use of natural fibers are as follows:

Technical innovations will make possible additional new manmade fibers and modifications of both natural and manmade fibers. In addition, new processing techniques will permit improvements in permanent press, soil resistance, and other desirable characteristics of natural and manmade fibers. Technology can also be expected to alter the farm production costs of natural fibers.

Blending of natural and manmade fibers in textile products is expected to continue. But present blend combinations may be altered due to improved methods for modifying natural fibers, to changing price relationships and to improved natural fibers resulting from genetic breeding.

Market research is expected to become more consumer oriented, with research on consumer purchasing behavior or psychology supplementing present quantitative market descriptions. Some questions needing study are the influence of cut, color, style, and design on the marketing of finished textile apparel, and the impact of increasing purchasing power among age groups sensitive to changing fashions.

Production capacity of present manmade fiber producers will expand, and additional firms may become fiber producers. For this and other reasons, research and development programs will continue to be needed to expand natural fiber markets.

Substitute Dairy Products

By Herbert H. Moede

Substitutes for fluid dairy products are of two general types: (1) Those using one or more components of milk as ingredients, and (2) those without any milk components. In both types, the products may have flavor, texture, palatability, and appearance similar to the natural dairy products. But usually their retail prices are significantly lower than those of their dairy counterparts.

The degree to which substitute products have replaced dairy products cannot be measured precisely in most instances, but most observers consider they have the potential to significantly change the demand for dairy products.

CURRENT SITUATION

Butter and Margarine

For many persons, margarine is a complete substitute for butter. Wide acceptance of this product came about primarily during and after World War II. In 1940, butter consumption totaled 17.2 pounds per capita. By 1950, it amounted to 9.1 pounds and, by 1967, had dropped to 5.5 pounds per person. The total decline for 1940-67 amounted to 12.2 pounds per person. On the other hand, per capita consumption of margarine rose from 2.4 pounds per person in 1940 to 10.5 pounds by 1967, a net increase of 8.1 pounds. This increase in margarine sales undoubtedly accounts for most of the decline in butter consumption, with the balance most likely resulting from shifts in the quantities of fat being used in diets.

Ice Cream, Ice Milk, and Mellorine

Mellorine, a substitute ice cream in which vegetable fat replaces butterfat, is sold legally in only 13 States. Sales of this product in the remainder of the contiguous United States have been made illegal through actions by the individual State legislatures. It cannot move in interstate commerce. Mellorine and ice cream substitutes are made by ice cream manufacturers.

Table 1 presents a comparison of the estimated per capita consumption of ice cream, ice milk, and mellorine in 1960 and 1967 for those States in which the sale of mellorine is allowed. Between 1960 and 1967, the estimated per capita consumption of mellorine decreased in four States, increased in five, and remained unchanged in two States. During the same period, consumption of ice cream rose in six States and declined in seven, while ice milk usage increased in 11 States, declined in one State, and remained unchanged in one State.

October 1967 retail prices for ice cream in Los Angeles, Calif., are typical of those existing in the western part of the country and ranged between 59 and 79 cents per half-gallon. Imitation ice cream (mellorine) prices were between 55 and 73 cents per half-gallon. Ice milk prices were 49 and 59 cents while prices paid for imitation ice milk were 39 cents per half-gallon. October prices for these products in Oregon were generally the same.

Coffee Whiteners and Whipped Toppings

D. L. Call of Cornell University estimated that nondairy coffee whiteners have taken 35 percent of the market for light cream.[2] He also considers that substitute toppings have taken more than half the total market for whipped toppings. Data from the 1963 Census of Manufacturers suggest that 80 percent of whipped toppings were nondairy products at that time. Federal Milk Market

[1] A major portion of this paper was previously published in the Dairy Situation, U.S. Dept. Agr., DS-320, May 1968.

[2] D. L. Call. Impact of Meat Analogs on the Livestock Industry. Talk at Cornell Nutritional Conference, Buffalo, N.Y., Oct. 1967, as reported in Feedstuffs, Vol. 39, No. 44, Nov. 4, 1967, p. 74.

Table 1.--Estimated per capita consumption of ice cream and selected substitutes, 1960 and 1967

State	1960			1967		
	Ice cream	Ice milk	Mellorine	Ice cream	Ice milk	Mellorine
	Gallons					
Ala.	2.6	1.2	0.1	2.3	2.0	([1])
Ariz.	2.7	.9	.2	2.6	1.1	0.7
Ark.	1.5	1.1	.5	1.6	1.3	.9
Calif.	3.5	1.4	.7	3.6	1.4	.8
Ill.	3.7	1.0	.3	3.8	1.1	.2
La.	2.7	.9	.2	2.3	1.2	.4
Mo.	3.7	1.4	.7	3.5	2.2	.4
Mont.	3.2	1.2	.5	3.0	1.6	.5
Nev.	2.9	1.4	([2])	1.7	1.1	([2])
Okla.	2.4	1.3	1.2	2.3	2.0	1.1
Oreg.	3.1	1.6	.4	3.3	2.3	.5
S.C.	1.4	.7	.1	2.1	2.2	NA
Tex.	2.2	.4	2.2	2.5	.5	2.2
13-State average	2.8	1.1	.8	3.1	1.4	.8

[1] Less than 0.1 gallon per person. [2] Not available.

Order data indicate that heavy cream sales dropped about one-fourth between 1956 and 1966.

Prior to the introduction of the substitute whiteners and toppings, coffee cream and whipping cream accounted for about 3 percent of milkfat consumption compared with 2 percent in 1966.

Basic formulas for coffee whiteners and substitute toppings are generally similar. The big difference between these products and their dairy counterparts is the substitution of vegetable fat for milkfat, and soy protein or sodium caseinate for nonfat milk solids. These ingredients are combined with emulsifiers, stabilizers, buffering agents, flavorings, and coloring agents.

Coffee whiteners and whipped toppings are made and sold by both dairy and nondairy companies. Retail prices for the whiteners are around 24 to 29 cents per pint while coffee cream prices range between 45 and 49 cents per pint. Nondairy whipped topping prices range between 35 and 39 cents per pint, compared with 50 to 75 cents per pint for whipped cream in pressurized containers.

Fluid Milk Substitutes

Substitutes for fluid milk are either (1) filled milk, in which nonfat milk solids--either fresh or reconstituted skim milk--are combined with vegetable fat in place of milkfat, or (2) synthetic milk, in which no component of milk is used. Synthetic products may contain sodium caseinate as an ingredient. The Food and Drug Administration considers sodium caseinate to be a chemical product derived from milk, but not falling within the meaning of "dairy products" as defined in the Federal Filled Milk Act.

Filled milk is not new, but the completely nondairy product is a recent development. Until recently, the sale of filled milks was prohibited by law in 32 States. However, court litigation and hearings before State regulatory authorities have raised questions concerning the constitutionality of the filled milk acts. Thus, filled milk is being allowed to be sold in more States. Few States prohibit sales of the nondairy product as long as it meets FDA labeling requirements and standards for wholesomeness. The Food and Drug Administration has published

Table 2.--Nutrients in market milk and synthetic milk

Nutrient	Market milk[1]		Synthetic milk[2]	
	Percent	Grams per quart	Percent	Grams per quart
Carbohydrate	4.9	48.00	6.8	66.00
Fat	3.5	34.00	3.1	30.00
Protein	3.5	34.00	.8	7.3
Ash	.7	7.0	.5	4.9
Calcium	.12	1.15	.02	.18
Phosphorus	.09	.91	.05	.46
Sodium	.05	.49	.07	.68
Potassium	.14	1.41	.36	3.50

[1] Based on the composition of fluid whole milk in: Newer Knowledge of Milk. 3d ed., Natl. Dairy Council, Chicago, Ill., 1965.

[2] Based on the analysis of a simulated milk product purchased in the Minneapolis-St. Paul market.

Source: S. T. Coulter and P. B. Manning. Speech at New Products Symposium, North Central Milk & Ice Cream Assoc., Minneapolis, Minn., Jan. 18, 1968.

proposals for standards for imitation milks and creams.[3]

Most filled products are made by combining coconut oil, fluid skim milk (or reconstituted nonfat dry milk), and a base mix. Coconut oil, like butter, is a highly saturated fat. However, a major supplier of fats and oils is selling a polyunsaturated fat--a combination of soybean and cottonseed oil--for use in filled or synthetic milk. Filled milk using this fat has been placed on sale in the Midwest. The ingredients listed on packages of filled products, in compliance with State labeling laws, indicate that the base mixes may contain monoglycerides and diglycerides, sodium caseinate, carrageenan, starch, and artificial coloring and flavoring. In addition, either corn sirup solids or soy protein, or both, may be used as a specific ingredient or included in the imitation base mix. The product also may be fortified with vitamins.

Major ingredients in a completely synthetic product are vegetable fat, protein, emulsifiers, buffers, stabilizers, body agents, and sweeteners. These products may also contain added vitamins, minerals, and coloring agents. Sodium caseinate is the usual major protein source.

Comparisons of the nutrients in market milk and synthetic milk in the Minneapolis market at the beginning of this year are shown in table 2. In this comparison, the synthetic milk contained lower levels of most of the listed nutrients, especially protein and calcium.

Both filled and synthetic products sold in other markets were analyzed under the auspices of the National Dairy Council. These tests indicated that the protein, calcium, and riboflavin content of filled milk were comparable with that of whole milk. These are the major nutrients which have given milk such an important role in human nutrition. Milk and dairy products supply about three-fourths of the calcium, one-fourth of the protein, and 40 percent of the riboflavin in the average American diet.[4] But the analyses also showed synthetic products to be quite low in these nutrients.[5] Vitamin A was absent in three of the four filled milk samples analyzed, but much higher than that of whole milk in the other filled milk sample and in the synthetic milk, both of which were vitamin fortified. Brink's discussion (see footnote 5) indicates a number of problems in formulating a product nutritionally equal to milk.

It is believed that these deficiencies can be substantially corrected by changing ingredients (although this may raise costs).

[3] Federal Register. Vol. 33, No. 98, Sat., May 18, 1968, p. 7456.

[4] Food Consumption, Prices and Income. U.S. Dept. Agr., Agr. Econ. Rpt. 138, Washington, D.C., July 1968, pp. 95-96.

[5] F. M. Brink. Comparing Nutritional Values of Filled and Imitation Milk. Amer. Dairy Rev., Vol. 30, No. 4, April 1968, p. 32.

However, consumers may not consider nutritional differences as important as nutritionists believe they are.

When vegetable fat is used in lieu of butterfat, the fat content of filled or synthetic products is somewhat lower than the minimum standard for fluid whole milk.

Ingredient Costs for Whole, Filled, and Synthetic Milks

Processing equipment and techniques used in making imitation fluid milk are much the same as those used in processing fresh fluid milk, and distribution is also similar. Therefore, cost differences for filled milk or synthetic milk and fresh fluid milk arise primarily from differences in raw material costs.

The average U.S. cost for fluid whole milk of 3.5 percent butterfat in April 1968 is estimated at 27.2 cents per half-gallon (table 3). When nonfat dry milk is used to make filled milk (without compensatory payments to make its price equal to that of Class I skim milk), the raw product cost for the filled milk is estimated at 14.9 cents per half-gallon. However, when the product is made from fresh skim milk at the average price dealers paid for bottling milk in April, the ingredient cost rises to 20.7 cents per half-gallon. The difference in cost between filled milk using Class I skim milk and whole milk would be 6.5 cents per half-gallon (table 3.) But the basic ingredient cost advantage for filled milk using reconstituted nonfat dry milk would be almost twice as large--12.3 cents per half-gallon.

For comparative purposes, a hypothetical formulation for a complete synthetic product is shown in table 4. This example cannot be considered typical of a current product, since soy protein isolate currently is not in general use for synthetic milk. The total ingredient cost for a completely synthetic product also might vary from the cost estimated in table 4 because the number and types of ingredients may differ among specific commercial formulations.

This estimated ingredient cost of synthetic milk is 13.0 cents per half-gallon, close to that for filled milk made from nonfat dry milk. If sodium caseinate were substituted for the soy protein, the total

Table 3.--Proportions of ingredients in filled milk, and estimated ingredient costs for filled milk and whole milk

Ingredient	Filled milk			Whole milk ingredient cost per half-gallon[2]
	Percentage of finished product	Estimated ingredient cost per half-gallon, using--		
		Nonfat dry milk[1]	Class I fluid skim milk[2]	
	Percent	Cents	Cents	Cents
Fluid skim milk (Class I).....	--	--	15.2	15.2
Nonfat dry milk.....	9.66	9.4	--	--
Vegetable oil.....	3.00	2.7	2.7	--
Milkfat.....	--	--	--	12.0
Emulsifiers and stabilizers...	.23	2.8	2.8	--
Total solids.....	12.89	14.9	20.7	27.2
Water.....	87.11	([3])	--	--
Total.....	100.00	14.9	20.7	27.2

[1] Based on nonfat dry milk at 24.5 cents per pound, refined vegetable oil at 21 cents per pound, and base mix (emulsifiers and stabilizers) at about $3 per pound.

[2] Based on the April 1968 price of $6.33 per cwt. dealers paid for 3.5 percent milk and a Class I butterfat differential of 8.0 cents.

[3] Less than 0.01 cent per half-gallon.

Table 4.--Estimated proportions of ingredients in a hypothetical synthetic milk, price per pound of ingredients, and cost of ingredients in finished product

Ingredient	Percentage of finished product	Price per pound	Estimated cost per half-gallon of finished product
	Percent	Cents	Cents
Fat (coconut oil)	3.00	21.0	2.7
Protein (soy protein isolate, 95 percent protein)	3.50	37.0	5.7
Emulsifiers (sorbitan monostearate)	1.00	40.5	1.7
Buffer (di-sodium phosphate)	.25	9.0	.1
Stabilizer (carrageenan)	.15	165.0	1.1
Body agent (corn sirup solids low D E)	3.50	8.0	1.2
Sweetener (sugar)	1.00	10.8	.5
Water	87.60	--	--
Total	100.00	--	13.0

ingredient cost could be higher because (1) it sells for about 50 cents per pound, compared with 37 cents for soy protein isolate, and (2) more sodium caseinate would be required to get the same level of protein content, as sodium caseinate is about 90 percent protein, while the soy protein isolate is 95 percent protein.

Statutory and Administrative Regulations

The Federal Filled Milk Act of 1923 prohibits the shipment of filled milk products in interstate commerce and defines the components of milk that fall within the provisions of the Act. Filled milk is listed as "any milk, cream, or skimmed milk, whether or not condensed, evaporated, concentrated, powdered, dried, or desiccated, to which has been added, or which has been blended or compounded with, any fat or oil other than milkfat, so that the resulting product is in imitation or semblance of milk, cream, or skimmed milk, whether or not condensed, evaporated, concentrated, powdered, dried, or desiccated." FDA considers a product containing sodium caseinate (but no other milk component as defined by the Act) is not a filled milk product and may be shipped in interstate commerce.

Over 30 States have laws or regulations which prohibit or limit the sale of filled milk products within the State. Many of these are patterned after the Federal Filled Milk Act. Since the summer of 1967, State filled milk acts or regulations have been challenged in the courts of at least six States: Georgia, Idaho, Washington, Alabama, Arizona, and Texas.

Standards of identity for either filled or synthetic milk have been established by California, Indiana, Louisiana, Mississippi, Missouri, Ohio, and Oregon. Generally, these standards are not as narrow as those for regular dairy products. For example, California requires a minimum fat content of 3.0 percent for filled and synthetic milk, but sets no nonfat solids minimum. Whole milk, however, is required to have a minimum fat content of 3.5 percent and a minimum nonfat solids level of 8.5 percent.

In fact, standards for many other dairy products, as well as whole milk, appear to be quite narrow and rigid. Butter, for example, is exactly defined by an Act of Congress and by some State standards which prevent the development of a lower fat--and lower priced--"butter." To permit the development and sale of a part milkfat-part vegetable fat spread in Wisconsin, the State legislature had to pass enabling legislation.

The somewhat rigid, narrow, and conflicting standards of identity and labeling requirements existing among the 50 States tend to restrict and reduce dairy product research and development. Such restrictions may limit the incentive to develop new dairy products.

Table 5.--Reported sales of filled milk, November 1967 to August 1968

Year and month	Federal order markets[1]	California[2]	Oregon[2]	New York Niagara Frontier market[3]	Rochester, New York market[3]
	1,000 pounds				
1967:					
Nov.....	2,368	2,681	508	(4)	(4)
Dec.....	3,329	2,921	518	(4)	(4)
1968:					
Jan.....	3,959	3,984	548	280	41
Feb.....	4,566	4,464	549	317	71
Mar.....	5,190	5,395	547	375	108
Apr.....	4,939	5,388	528	336	117
May.....	5,081	5,966	517	334	116
June....	4,623	5,438	442	269	100
July....	5,125	5,824	433	246	80
Aug.....	5,274	5,844	441	237	71

[1] Based on Federal Milk Order Market Statistics.
[2] May not include all of the sales in these markets due to reporting restrictions. California data may include a small amount of synthetic milk and is based on August 1968 Dairy Information Bulletin, California Crop and Livestock Reporting Service issued October 1968.
[3] Based upon quantities of "Melloream" produced. [4] Not available.

Current Sales of Filled and Synthetic Milk

Currently, sales of filled and synthetic milk are reported for the Federal order markets and for the California, Oregon, New York Niagara Frontier, and Rochester markets (table 5). In May 1968, about 5.0 million pounds of filled milk was sold by 62 handlers in 30 Federal order markets, representing about 0.4 percent of total Class I sales in these markets. Synthetic milk was sold in 10 Federal order markets by 15 handlers. In these markets, prices of filled and synthetic milk were generally 5 to 7 cents lower per half-gallon than prices of whole milk. In the contiguous United States, the Central Arizona market probably has the longest and best documented history of filled milk sales. Filled milk sales during October 1966 in this market were 1.3 percent of regulated pool plants' Class I sales. This share rose steadily to 7.8 percent in March and to 11.5 percent in August 1968.

In California, filled milk sales during most of 1966 averaged about 0.02 percent of total monthly Class I sales. However, in March 1967, filled milk sales were 0.04 percent and, by August 1968, reached 1.3 percent of the total Class I product sales. Sales of synthetic milk are not reported.

Oregon presents a somewhat different picture. Imitation milk sales in July and August 1967 were 1.3 percent of total Class I milk sales, slightly lower than for November 1967-August 1968.

Sales increases for filled and synthetic milk in Hawaii were phenomenal. In August 1967, imitation milk accounted for less than 0.1 percent of Class I sales in the Honolulu market. Heavy promotion and a wide price advantage for imitation milk brought increases in sales each month. By December 1967, imitation milk sales attained 20.4 percent of Class I sales, while their percentages of Class I sales for the first 4 months of 1968 were 17.2, 16.8, 16.5, and 19.7, respectively.[6]

COMPETITIVE EFFECTS

Imitation (filled milk) and synthetic dairy products can have different effects on the demand for market milk. Imitation dairy products using one or more components of milk in their formulations have less impact on the demand for market milk than a

[6] Division of Milk Control, Hawaii Dept. Agr., Honolulu, Hawaii.

completely synthetic dairy product. A completely synthetic product can use ingredients derived from agricultural sources combined with ingredients from materials not originally derived from agricultural products. Thus, increases in the number and volume of synthetic products on the market will lead to some loss of markets for specific agricultural commodities and product demands will shift from one agricultural commodity to another as well as to suppliers outside of agriculture--to food processors and chemical companies.

TECHNOLOGICAL AND ECONOMIC FACTORS AFFECTING DEVELOPMENT OF SUBSTITUTES

Substitute dairy products in most instances can be produced and marketed in one or more of three forms--liquid, frozen, and dry. The basic ingredients in each of these forms are similar: Fats, emulsifiers, stabilizers, and protein or carbohydrate bodying agents. The fat usually has been coconut oil; however, one recent development has made available a fat consisting of mixed cottonseed and soy oils. The emulsifiers are fatty acid esters such as sorbitan monostearate or polyoxyethylene sorbitan tristearate; the stabilizers are sodium citrate, tetrasodium pyrophosphate (sodium pyrophosphate), dipotassium phosphate, carrageenan, carboxymethyl cellulose, sodium alginate, and locust bean gum or guar gum; the bodying agents are calcium caseinate, potassium caseinate, soybean proteinate, corn sirup solids, sucrose, and lactose. The actual percentage of each basic ingredient in a finished substitute dairy product varies among products.

The development of substitutes has progressed with advancements in lipid and food technology. For example, solvent fractionation, hydrogenation, and other alterations of the molecular structure of fats permit the formulation of products having the texture, taste, and appearance of dairy products. These vegetable fat products can generally be processed and packaged with equipment presently used in dairy processing plants plus utilizing present transportation and storage facilities. Quality control during processing is facilitated by the commercial availability of premixed basic ingredients in liquid and dry forms.

Several product characteristics influence the market success of substitute dairy products. Dry forms of the substitutes have a long shelf-life and liquid forms generally require a minimum amount of refrigeration. Each of the forms--liquid, dry, and frozen--is readily adapted to consumer packaging. Some product differentiation is also possible by slightly altering the ratios of the basic ingredients. For example, an all-vegetable creamer can be obtained by the replacement of caseinates with soybean proteinates or some other bodying agent. This makes the substitute creamer acceptable to consumers who must restrict their intake of animal products for religious or dietary reasons.

ADJUSTMENTS IN THE DAIRY INDUSTRY TO MEET COMPETITION

To meet competition from filled and synthetic dairy products, the industry has taken some significant steps. In the last few years, new dairy products which fall within the rigid framework of the existing standards of identity have been developed. Ice milk, for example, was developed to compete with mellorine-type frozen products. And currently in Wisconsin, market testing is underway on a low-butterfat dairy spread.

The industry has begun processing the imitation products in dairy processing plants and marketing them along with traditional dairy items. This undoubtedly reflects an attempt to prevent either the food processing industry or vegetable oil processors from capturing the total market.

Another response to imitation milk is found in the Midwest. When the product was introduced there, some sellers met the competition by selling low-fat milk (2 percent butterfat) at 3 half-gallons for $1 in some markets. This indicates that low-fat and skim milk can compete with imitation milk, when the dairy product ingredient cost is fairly close to that of the imitation.

Some Alternative Approaches to the Problem

Filled and synthetic milk currently enjoy price advantages over whole milk. Legal barriers which deterred their sale appear to be giving way. Also, the consumption trend away from milkfat seems to have depressed sales of whole milk in recent years and opened a place for new products, especially those which are more convenient and lower priced than the traditional dairy products.

Former Secretary Freeman spoke of filled and synthetic milk in these words: "Regardless of the views held within the dairy industry of these products, I believe we have to recognize they are here and deal with them as competitive products..... In relation to the question of how to handle filled milk, I believe a more effective answer could be found in direct payment programs than in trying to prohibit or restrict its access to commercial markets."[7] He also recognized the need to explore opportunities for broadening dairy consumption through strengthened education, promotion programs, and new and diversified product development.

SUMMARY

Since 1960, substitute dairy products have taken more than half of the butter market, a substantial share of the market for cream, and 15 percent of the frozen dessert market in the 13 States where mellorine can be sold. These substitute products have the potential to revolutionize consumers' eating habits and to cause significant changes in the demand for dairy products.

Imitation dairy products are of two general types: Those that use one or more components of milk as ingredients, and those that use only nondairy ingredients in their manufacture. Currently, imitation fresh fluid milk products are coming into the market. Some are synthetic products using no milk components, but most of those introduced so far have been filled milk with vegetable fat substituted for milk fat.

Filled milk and synthetic dairy products can have different effects on the demand for market milk. Imitation products using one or more components of milk in their formulations have less of an impact on the demand for milk than a completely synthetic product.

The difference in raw material costs (averaging about 13 cents per half-gallon) primarily accounts for the cost difference between the imitation product and fresh fluid milk.

To meet competition from filled and synthetic dairy products, the dairy industry has developed some new dairy products which meet the existing standards of identity.

The industry has begun processing imitation products in dairy processing plants and marketing them along with traditional dairy items.

[7] Remarks by former Secretary of Agriculture Orville L. Freeman at the annual meeting of the Maryland-Virginia Producers Association, March 28, 1968, Washington, D.C.

Synthetics and Substitutes for Cereal Products

By Norman L. Rollag, Carl J. Vosloh, Jr.
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CURRENT SITUATION

Industrial Cereal Products and Substitutes

Cereal products are the major source of carbohydrates for food products and animal feeds. Synthetic substitutes do not generally compete with cereal products for this purpose, although cereals compete with each other. The competitive situation is altered when cereal products are used for industrial purposes. In these markets, synthetic products actively compete with cereal products. The current industrial markets in which cereal products face intense competition from synthetics are summarized in table 1.

Technical progress has been made in developing starches and derivatives having specific physical, chemical, and functional characteristics. Numerous organic and inorganic derivatives have been developed which have uses in industrial applications. The possibility of maintaining or improving the competitive position of cereal products in industrial markets depends on the continued development of specialized starch derivatives. Basic and applied research by commodity associations, cereal product processors, and other agencies must be continued if cereals are to maintain the same technological development rate as substitutes.

Prices of Cereals and Substitutes

Many natural and synthetic materials compete with cereal products in the adhesives market. These are summarized with their current price ranges in table 2. A deterrent to expanded demand for cereals

Table 1.--Major industrial products of cereals and competing materials

Cereal products	Major markets	Competing material (natural and synthetic)
Starch (corn, wheat, and sorghum).	Textile, paper, adhesives	Natural: Tapioca starch, casein, soya protein, natural gums Synthetic: Carboxymethylcellulose, urea-melamine resins, vinyls, acetates, epoxies, neoprene, nitriles, acrylics, aldehydes
Grain (corn, wheat, sorghum, rye, and barley).	Ethyl alcohol	Natural: Molasses, other grains Synthetic: Sulfite liquor, ethylene gas, ethyl sulfate
Flour (corn, sorghum).	Foundry binders, gypsum board, ore refining, oil well muds	Natural: Natural gums Synthetic: Carboxymethylcellulose, phenolic and silicone resins
Wheat.....	Adhesives, composition boards	Natural: Natural gums, casein, other grain starches, soybean protein

Table 2.--Price ranges for natural and synthetic materials, 1967

Raw material	Cents per pound
Natural (cereal):	
Corn and sorghum starch and flour[1]	4.5 - 5.5
Wheat starch and flour[1]	5 - 7
Natural (other):	
Arabic gum	20 - 25
Blood albumin	12 - 15
Blood, dried	10 - 14
Bone glue	15 - 20
Casein	20 - 25
Hide glue	19 - 25
Rosin	15 - 20
Rosin esters	20 - 25
Soybean flour	5 - 7
Soya protein	20 - 25
Tapioca	3.5 - 5
Synthetic:	
Acrylics	35 - 40
Butadiene-acrylonitrile latex	40 - 50
Butadiene-styrene resin	25 - 30
Carboxymethylcellulose	45 - 55
Coumarone-indene	10 - 12
Epoxy resins	55 - 60
Ethyl cellulose	55 - 65
Melamine-formaldehyde resin	30 - 40
Neoprene	35 - 40
Phenolic resins	20 - 25
Polyamide resins	80 - 90
Polyester resins	25 - 30
Polyurethane	50 - 60
Polyvinyl acetate	25 - 30
Polyvinyl alcohol	40 - 45
Polyvinyl butyral	90 - 100
Polyvinyl choloride	15 - 20
Resorcinol-formaldehyde	80 - 90
Rubber	25 - 30
Sodium silicate	3 - 4
Styrene-butadiene rubber	20 - 25
Urea-formaldehyde resin	10 - 18
Urea-melamine resin	20 - 25

[1] The price of raw starch. Starch derivatives would have a higher price depending on the types required for specific end-uses.

Sources: (3, 9, 16, 17, 18).

in industrial markets has been the ability of synthetics to compete effectively, even though the price structure for synthetics is noticeably higher. This condition would suggest that synthetics have a competitive advantage in meeting the technical requirements of the market.

Quantities of Cereals Used in Industry

The quantity of natural and competing synthetic raw materials utilized in selected end-use markets is estimated to be 4.8 billion pounds (table 3). Corn and sorghum are considered the major raw material sources, although competition from synthetics is becoming more intense. This competition can be expected to continue. The miscellaneous industrial markets include composition and gypsum board, foundry binders, aluminum ore refining, laundries, charcoal briquettes, and oil well drilling muds.

Wheat

Relatively small amounts of wheat and wheat flour are presently consumed industrially (5).[1] Corn, sorghum, and tapioca are available in more than adequate supplies. Many of these are priced lower than wheat, at least for general use. Some of the past industrial markets for cereal grains have been lost. For example, practically all industrial ethyl alcohol is now produced synthetically from nonagricultural raw materials.

Wheat flour is utilized in such major markets as, for example, extenders for plywood and laminating urea-formaldehyde adhesives, composition-boards, and wallpaper paste. Loss of these markets would detract from the economic value of wheat as a crop. As a food grain, however, wheat commands a price that is generally unfavorable to its utilization as an industrial raw material.

Although the principal use of wheat is as food, over 300 million pounds of wheat starch and flour were consumed by industry in 1966. The industrial use of starch is the equivalent of about 6.8 million bushels of wheat. As a range, the consumption would be between 6 and 8 million bushels annually. Most of the wheat flour and starch is produced as coproducts of the milling industry. These products compete for food as well as industrial markets. Even though the special properties of the wheat components are desired in industrial products, economic considerations play a dominant role in their use.

[1] Underscored numbers in parentheses refer to items in the bibliography, p. 32.

Table 3.--Estimated quantities of cereals and competing natural and synthetic raw materials utilized in various end-use markets, 1966

Industrial uses	Raw material sources[1]				
	Cereal flours and starches		Other natural materials[2]	Synthetic materials[3]	Total
	Wheat	Corn and sorghum			
	Million pounds				
Paper	[4] 45	[4] 1,415	395	200	2,105
Adhesives	215	390	70	1,010	1,685
Textiles	5	350	--	270	625
Miscellaneous	40	270	--	--	310
Total	305	2,425	465	1,530	4,725

[1] The midpoints of the ranges indicated in tables 4 and 5 are used for developing these figures.
[2] Includes casein; potato starch; soy flour, proteins, and isolates; and tapioca.
[3] Includes synthetic resins, carboxymethylcellulose, and polyvinyl alcohol.
[4] Some of these materials are also used to produce adhesives.

Wheat, like corn and sorghum, is used industrially as starch and flour. Wheat starch is a coproduct in the production of vital gluten from a product of the milling industry called clears. The high cost of wheat flour clears has made it difficult for wheat starch and gluten producers to compete effectively with imported materials.

For most purposes, wheat starch must compete on a price basis with other starches. In only a few uses, such as in commercial laundries and certain types of adhesives, are the properties of wheat starch such that it can command a premium over other starches. Because of special properties, wheat flour has long been a favorite material for wallpaper paste. Although wheat flour still dominates this market, its use has declined in recent years because of the steady decline in the consumption of wallpapers.

The major industrial use of wheat flour is as an extender for urea-formaldehyde resin adhesives used in hardwood and to a limited extent in softwood plywood. Wheat flour makes up one-half to two-thirds of total solids in these adhesives. Consumption of hardwood plywood in the United States increased from 1.5 billion square feet in 1951 to 4.7 billion in 1966. A substantial part of this increase, however, was in imported hardwood plywood from Japan, Korea, the Philippines, and Taiwan. Imports accounted for only 5 percent of consumption in 1951 compared with 57 percent in 1966. Domestic production increased from 1.5 billion square feet in 1951 to 2.2 billion square feet in 1966.

Wheat flour is also used as a resin extender in the production of laminated cabinet doors and other furniture items and as a binder and stiffening agent in insulating board.

Corn

About 2.7 billion pounds of cereal starches and flours are used annually in the United States for industrial purposes. Corn is the source of most of these products. Industrial outlets for starches and flour are, however, constantly threatened by synthetic products derived from nonagricultural sources.

The domestic corn wet-milling industry produces about 80 percent of the industrial starch used in the United States. Dry-milled corn and sorghum products account for about 11 percent and wheat about 8 percent. The remaining industrially used starch is imported.

The expanding industrial economy has provided a growing outlet for cereal products. The growth in starch shipments by the corn wet-milling industry closely parallels the growth in gross national product.

For this reason, GNP serves as a useful indicator of the aggregate demand for starch. Shipments to industrial users, as opposed to food users, have accounted for an increasing share of the total--from 67 percent in 1950 to an estimate of nearly 90 percent in 1966.

The growth in starch markets has been in sharp contrast to the growth in wheat flour consumption. Cornstarch shipments averaged approximately 3.3 percent annually whereas wheat flour consumption increased at an average rate of only 0.6 percent. The growth in wheat flour is about 1.7 percent slower than population growth and reflects a decline in per capita consumption.

Industrial chemicals provide a multi-billion-pound annual market in which starch-derived products should share to an increasing extent. At 5 to 6 cents per pound, cornstarch is an attractive raw material for the manufacture of industrial chemicals. When fermentative rather than conventional chemical conversion is applicable, even cheaper sources of starch such as flour and ground whole grain can be used as the raw material. Also, over 150 million pounds of corn sugar is used annually in the manufacture of such well-known industrial chemicals as sorbitol, mannitol, citric and gluconic acids, and methyl glucoside.

Grain Sorghum

The growing importance of grain sorghum as a competitive crop is revealed by the record 765-million-bushel crop in 1967. About 80 percent of the grain sorghum crop is grown in Texas, Kansas, and Nebraska. Sorghum, starch, and flour find industrial usage where freight transportation advantages exist. Currently, an estimated 6 million bushels of sorghum are milled for products consumed mainly by the paper and gypsum board industries.

Dry-millers of both corn and sorghum have intensified their efforts in recent years to capture a larger share of the industrial market. They have had considerable success by working closely with industrial users to adapt their products to meet the requirements of the market. In some applications, the more refined and more costly cereal starches have been displaced. In others, new markets for dry-milled corn and sorghum products have resulted. Because of their relatively low cost, the volume of these materials can be expected to increase in uses that can tolerate their nonstarch constituents.

Industrial End-Use Markets

Estimated volumes of selected cereal products and substitutes used in selected end-uses are shown in tables 4 and 5. Natural and synthetic products compete with cereal products in the paper, textile, and adhesive industries. The major natural substitutes are casein, imported tapioca starch, potato starch, soybean flour, and

Table 4.--Estimated volumes of cereals and other materials used in the paper and textile industries, 1966

Material	Paper	Textiles
	--Million pounds---	
Natural:		
Casein	32 - 35	--
Corn and sorghum starch and flour	1,413	350
Potato starch	45 - 60	--
Soya protein	30 - 35	--
Tapioca	270 - 278	--
Wheat starch and flour	45 - 48	5
Synthetic:		
Carboxymethylcellulose	4	5 - 6
Polyvinyl alcohol	6	4 - 5
Synthetic resins	240 - 262	260

Sources: (2, 3, 4, 9, 10, 11, 13, 14, 18)

Table 5.--Estimated volumes of cereals and other materials used in adhesives, 1966[1]

Raw material	Million pounds
Corn and sorghum:	
Starch and flour	190 - 200
Dextrine	190 - 200
Wheat starch and flour	170 - 180
Soybean isolate	7 - 10
Soybean flour	55 - 65
Synthetic resins[2]	1,011

[1] Does not include cereal products used in paper and textile industries.

[2] The annual growth rate for synthetic resins used in adhesives and binding was 13.8 percent for 1950-65.

Sources: (3, 4, 11, 12, 13, 14, 18).

soybean protein. Synthetic substitutes include carboxymethylcellulose, polyvinyl alcohol, and numerous synthetic resins. Approximately 42 percent of the market for cereal products and synthetics in the end-use markets shown in table 3 is derived from noncereal sources.

Paper and Paperboard

The largest and fastest growing market for cereal starches is the paper and paperboard industry. In recent years, this industry has accounted for 50 to 60 percent of all industrial use of cereal starches.

Starch is used in manufacturing paper and paperboard for four major reasons: (1) As a wet-end additive to improve strength and toughness of the paper sheet and reduce beating time, (2) as a surface-size to improve printing qualities and to lay fuzz, (3) as an adhesive in paper coatings, and (4) as an adhesive in the manufacture of corrugated paperboard containers and other packaging materials.

Starch use in paper has increased at a rate of 5.6 percent per year. The increased use of starch in paper has offset some losses in other industrial markets. Each increase of 1 million tons in paper and paperboard production is associated with an increase of 45 million pounds of starch used by the industry. If this continues, use of starch by paper mills can be expected to reach 1.5 billion pounds in 1970.

Textiles

The textile industry is the second largest industrial market for cereal starches, accounting for about one-sixth of total industrial cereal use. Use of starch by this industry appears to have leveled off around 300 million pounds in recent years. The most important uses of starch in textiles include: (1) As a warp size to strengthen and protect the yarn during weaving, (2) as a thickener in textile printing pastes, and (3) as a stiffening and firming agent in the finishing of fabrics. Warp sizing accounts for 75 to 80 percent of the total.

A major problem in the use of starch in textiles has been the pollution of water supplies by textile mill wastes. Fifty to sixty percent of the biological oxygen demand of textile mill waste is attributed to the starch used as warp sizing. However, stream pollution from detergents that were not biodegradable appears to have taken away some of the concern about starch use in textiles.

Furthermore, a recent Department study suggests that, for most textile mills, the cost of starch plus its waste effluent treatment would probably be less than the cost of using synthetic resins (6). Starch waste effluent has been considered a greater source of stream pollution than synthetic resins. However, there is some question about the reliability of laboratory tests used to evaluate pollution potential when applied to stream conditions.

The use of synthetic resins in textile finishing has reduced the amount of starch used in the industry. Also, starch use in home and commercial laundries is threatened by the use of synthetic "starches." Significant expansion in use of cereal starch in textiles does not appear likely at the present time.

Adhesives

Adhesives represent a market long dominated by starch. They account for nearly half of the annual 2-billion-pound starch market. However, competition by synthetic resins is especially effective because of the specialized properties required to increase production of products like corrugated container board on automatic machinery. The overall growth rate of adhesive consumption is about 7 percent per year.

The production of adhesives in the United States was 0.9 and 1.2 billion pounds in 1954 and 1963 respectively (15). However, these estimates exclude imports, production for inplant use, and production by synthetic resin producers. Estimates for cereal adhesives are understated since large quantities of cereal adhesives are produced in the users' plants. Approximately 20 to 25 percent of the adhesives produced in plants classified by the Bureau of the Census as primary adhesive producers use some cereal products. The estimated volumes of selected materials used in adhesives in 1966 are shown in table 5.

Adhesive formulations must be tailored to meet changing technical requirements of users such as viscosity, methods of application, and resistance to biological, chemical, or weather degradations. For example, the adhesive formulations required by plywood producers differ from the formulations required by producers of pressure-sensitive tape. Another factor in adhesive formulation is the need to meet local building code specifications.

Other Industrial Uses

The use of cereal products for the production of ethyl alcohol is declining (1). The annual growth rate of total ethyl alcohol production between 1945 and 1965 was 2.2 percent. Production from synthetic raw materials was 8.6 percent and natural raw materials was -8.4 percent. These trends are expected to continue.

The technical disadvantage of using cereal products in the production of ethyl alcohol is the low yield of alcohol per unit of cereal input.

Cereal products, primarily starches, flours, and dextrose, are used in many other industrial markets such as ore refining, and pharmaceutical and chemical intermediates. The volumes used in these markets are estimated at 305 million pounds of flour and starch and 151 million pounds of dextrose. Other markets such as coatings, plastics, elastomers, and thickeners represent additional outlets in which starch-derived products having suitable properties should find ready acceptance.

TECHNICAL FACTORS AFFECTING COMPETITIVE SITUATION

Cereal Composition

More cereal grains are being used industrially than ever before. Almost 2 billion pounds of cereal starches alone are used by industry annually, an increase of more than 300 percent during the past 30 years. Yet wheat has not shared in this industrial growth, primarily because of its higher price.

Wheat starch has smaller granules than corn or sorghum starches and the physical properties of wheat gluten differ greatly from those of corn or sorghum gluten. Wheat gluten has unique hydration, extensibility, and elasticity properties not available in other cereal grains and has a potential plus value for the development of specific industrial markets. Adhesives, coatings, and paper sizings are typical of these markets.

If the costs of the wheat and of the processing are distributed equally over all of the separated fractions, wheat starch would normally be more expensive than other cereal grain starches. If, however, one or more of the fractions can be sold at a higher price and carry more of the cost, the remaining components may be reduced in price so as to compete. The higher gluten value makes it possible to sell the starch at a cost close to the general starch market prices.

Processing of Cereals

The relatively new milling techniques of fine grinding and air classification offer possibilities for adjusting the composition of wheat flour. From a flour containing 7 percent protein, fractions have been obtained containing as high as 20 and as low as 3.1 percent protein. The low-protein fraction may be a good industrial product for many uses based on starch. Preliminary tests in the paper industry have shown it to be suitable for internal paper size. The high-protein fraction from certain wheat varieties is an excellent blending flour for fortifying or adjusting the protein content of other flours. This premium value may, under certain conditions, make it possible to pay the added processing costs and yet lower the price of the starchlike fractions so that they can compete in industrial markets.

Chemical modification of wheat flour to take advantage of its starch and gluten properties is another approach to the development of industrial products. Modification can be directed either toward general improvement or toward capitalization on the properties of both starch and gluten.

Developing New Markets

A constant flow of new or improved products is one way of insuring continued growth in industrial markets for cereal products. There are many new or relatively new cereal developments which show promise. High-amylose starch promises to capture new markets in films and fibers. Dialdehyde starch is competing in the southern plywood adhesive market which is dominated by synthetics; it also shows promise as a paper additive. Cereal xanthates offer promise of new uses for cereals in paper and paperboard. Several cereal-starch derivatives show promise of increased use in the rapidly expanding urethane foam markets. There are a number of new developments which add to the favorable outlook for continued growth in industrial markets for cereal.

Recent Developments

A new process has been developed for making polyethers from starch for use in the production of rigid urethane foam (7).

Rigid urethane foam from all sources is sold at a rate of 100 million pounds per year. Estimates are for production to reach 280 million pounds by 1969. The increasing demand is due to its high insulation capacity, which is about twice that of nonurethane foams. The construction, transportation, and appliance industries are the major consumers of rigid foams. The amount of starch-derived polyether used in making 100 pounds of foam requires 13 to 15 pounds of starch.

Polysaccharide gum has been selected by industry as the base component for a new patented oil well drilling mud system (8). The market exceeds 1 million pounds annually and rapid growth is predicted. This gum is produced by a process based on bacterial fermentation of cereal starches. About 2 pounds of starch are used to produce 1 pound of gum. Gum solutions in water have unusually high viscosities that are stable over wide ranges of conditions normally encountered in oil well drilling.

Wheat flour fractions modified by a new process have been used by the paper industry in the Pacific Northwest. The process involves the enzymatic conversion of the flour to a desirable form and is readily applicable in existing papermills. It can be used with various types of flour, but best results are with soft wheat flour. When the process is used, the industrial-grade flour produced in the region can compete with other commercial products currently used as paper size.

Cornstarches containing various amounts of amylose are now commercially available. Two starches are marketed, one containing 50 to 60 percent amylose and one containing about 70 percent amylose. The starch in yellow dent corn contains only about 27 percent amylose. In general, the film-forming properties of starch improves in proportion to its amylose content. Growing industrial markets for the new starches are found in the manufacture of glass fibers and paper products. Other potential uses include edible coating for foods.

A process has been developed for the chemical modification of cereal flours as surface-sizing agents for paper (7). The acid-modified flours' performance on paper machines and the quality of the finished paper are about equal to high-grade modified starches now in commercial use.

The paper industry uses about 600 million pounds of corn and sorghum products per year for surface-sizing and the gypsum board industry uses over 50 million pounds.

Future Technical Developments

Technical developments in plastics, fibers, ceramics, glass, metals, and resins favor the use of synthetic over natural raw materials. Synthetic resin producers actively promote the use of synthetics in adhesives. These producers not only produce adhesive raw materials, but develop and market completely formulated adhesives.

The cereal processing industry is faced with a fluctuating price structure for raw materials (corn, wheat, and sorghum). Intraindustry technical development will be influenced by the stability of prices. Without stable prices, cereal products will be at a competitive disadvantage relative to synthetics. Over the past decade, competing synthetics have had stable or declining prices.

Future technical research in cereal grains will be directed toward development of new products or processes which will assist cereal-derived industrial products to compete more effectively with their synthetic substitutes.

New areas of research to reduce processing costs include (a) lower cost processes for polyethers used in urethane and other synthetic resins, (b) improvements in the film-forming ability of starch and starch derivatives, (c) improvements in the water permeability of soluble film and sealing films, and (d) improved methods of extruding water-soluble film to increase processing speeds.

New product requirements include (a) developing new starches to meet adhesive requirements in new materials such as plastics, (b) developing compatible adhesives for use in volatile organic solvents, (c) development of internal plasticizers for water-soluble film, and (d) improvement in high-amylose hybrid grains, especially for industrial purposes.

Cereal products in industrial markets will continue to face intense price competition from synthetics. Over the past decade, prices of synthetics have declined and their technical performances are constantly being improved. A second feature of the industrial market environment tending to intensify competition is the entrance of large integrated synthetic producers that provide raw materials and completely formulated synthetic products that are "ready-to-use."

There are a limited number of firms producing industrial products from cereals and these are highly homogeneous in terms

of geographic locations, production capacities, production methods, and source of raw materials. These firms have been able to support a basic research and market development organization which disseminates technical information to users and provides assistance in developing new products using cereal products. The organization also provides each firm with market information relative to volumes marketed and changes occurring in end-use patterns. The major disadvantages of the firms' homogeneity are the inability to differentiate products other than through brand promotion and the limiting of potential firm expansions except through a conglomerate arrangement.

Some possibilities for future change are:

1. Movement of processing plants closer to final users.
2. The expansion of firms through the enlargement of their product mix with a heavy emphasis on high-value food products rather than industrial products.
3. Emphasis of market development research toward the large-volume outlets in which cereal products are well established.
4. New industrial products from cereals, which will require more complex processing, thus reducing the competitive advantage of commodity identity and low price.

FUTURE MARKET ADJUSTMENTS

Industrial Market Adjustments

The most promising outlets for new and improved industrial products derived from corn include the paper industry, industrial chemicals, adhesives, protective coatings, plastics, elastomers, and thickening agents.

The greatest opportunity exists in the manufacture of paper and paperboard products. U.S. production is over 40 million tons per year and growing at a faster rate than population. The total volume of starch consumed in the paper industry as well as the average amount used per ton of paper products has increased substantially since 1950. To maintain or to increase the utilization of cornstarch and flour in competition with synthetics, new concepts must be evolved with specific emphasis on the properties imparted to paper products.

To achieve an increase in the use of wheat starch, research is needed to provide new and improved properties such as water resistance, dispersibility, paste viscosity, tack, and adhesive bond strength. The possibilities of achieving some of these improvements by modification of the gluten component of flour should be investigated. Conditions must be established for optimum use of industrially promising products such as acid and enzyme-modified flours and xanthated bran and millfeeds.

Since starch is usually cheaper than synthetic adhesive resins, prospects are good for meeting the competition through research to improve viscosity properties, bond strength, tack, and drying time of starch-derived adhesives for specific end-uses.

Research on sorghum starch is integrated with that on cornstarch. Because grain sorghum has a round kernel in contrast to the odd-shaped kernel of corn, it lends itself to dry-milling innovations not possible with corn. Improved milling technology, with the advantages of air classification of sorghum flour, offers prospects for increasing industrial utilization by making processing costs more attractive and by providing products with superior properties.

Technology suited to the specific characteristics of sorghum and its milled products must be developed. This is needed to maintain its market despite synthetic competitors and to take advantage of its economical production.

Public Action and Research Programs

Government grain programs as they exist are not designed specifically to encourage or increase industrial use of cereal grains. Industrial use of grains is very small compared to food or livestock feed uses.

Increased industrial uses have been retarded because grain prices are high and are too variable over short periods of time. This situation has tended to reduce any advantages obtained from expanding present industrial uses as well as establishing new uses.

One method of increasing the use of cereal grains industrially is through increased utilization research. Government and private utilization laboratories have undertaken numerous projects designed to develop new markets for cereal products. Further efforts to develop new uses for cereal grains should include an aggressive program of market research and economic analysis.

Such a program should include the following objectives: (1) To assess the economic feasibility of proposed new research

and development projects, (2) to maintain a balance between the technical and economic aspects, and (3) to develop short- and long-term forecasts of new industrial products, markets, and trends.

Greater success might be realized if industry took an active role in the program. The more intimately an industrial user can be associated with the research task, the more rapidly the research results can be translated into production.

It is imperative that research and production planning be properly directed to meet the specifications of the ultimate consumer. Considerable effort has gone into this endeavor during recent years. However, there remains a need for an integrated long-range program of both fundamental and utilization research, which will lead to new and economic uses for cereal grains by taking advantage of their inherent values.

SUMMARY

Cereal grains are the major source of carbohydrates for human foods and animal feeds. However, there is a relatively small, but important, industrial market for cereals. Cereal starch and flour are used in the manufacture of textiles, paper, adhesives, building materials, and other varied products. In these markets, cereal products must compete with other natural and synthetic materials.

Technical progress has been made in developing cereal starches and derivatives having acceptable physical, chemical, and functional characteristics. The possibility of maintaining or improving the competitive position of cereals in industrial markets is dependent on the continued development of specialized starch derivatives.

Industrial cereal products have been unable to compete with synthetics in several markets even though they have a favorable price structure. Thus, it seems that manufacturers of synthetics have been able to develop materials that meet the technical requirements of these markets. The specifications for these raw materials can be expected to become more rigid.

The paper industry accounts for about 52 percent of the total cereal industrial market. Twenty-one percent goes into adhesives, 15 percent into textiles, and the remaining 11 percent into other industrial uses.

Major end-use markets for textiles include warp sizings in yarn weaving, thickeners in textile printing pastes, and firming agents in the finishing of fabrics.

The composition of individual cereal grains varies considerably. Wheat starch contains smaller granules than corn or sorghum starches. Wheat gluten has unique properties of hydration, extensibility, and elasticity not present in other cereals and is potentially important in the development of specific markets. Also, new milling techniques offer possibilities for adjusting the composition of wheat flour to meet more critical industrial needs.

Government grain programs in past years have not been specifically designed to encourage the industrial use of cereals. Private utilization research programs will be required to encourage new and expanded markets for cereal grains.

BIBLIOGRAPHY

(1) Corkern, Ray S.
1967. Synthetic Substitutes in Agricultural Markets. U.S. Dept. Agr., ERS-356.

(2) Grief, Donald S.
1962. Uses and Challengers for Starch in the Paper Industry. Paper Trade Jour. 146(50): 43-45, Dec. 10.

(3) Heidinger, H. C., and Cantor, S. M.
1965. A Study of Soybean Protein Isolate. Sidney M. Cantor Assoc., Inc., June 1.

(4) John T. Fosdick Associates, Inc.
1960. The Market For Chemicals in the Paper and Pulp Industry. Lockwood Trade Jour. Co., Inc.

(5) Miller, Dwight L.
1965. Industrial Uses of Wheat and Flour. Fourth Natl. Conf. on Wheat Util. Res., Boise, Idaho, Nov. 3-5.

(6) Moore, Clarence A.
1967. An Economic Evaluation of Starch Use in the Textile Industry. U.S. Dept. Agr., Agr. Econ. Rpt. 109.

(7) Northern Utilization Research and Development Division.
1965. A Summary of Current Program, 7/1/66 and preliminary report of progress for 7/1/65 to 6/30/66. U.S. Dept. Agr.

(8) _____
1966. A Summary of Current Program, 7/1/67 and a preliminary report of progress for 7/1/66 to 6/30/67. U.S. Dept. Agr.

(9) Oil, Paint and Drug Reporter.
1967. Schnell Publishing Co., Inc., New York, N.Y.
(10) Paperboard Packaging.
1966. Papermaking Chemicals. Vol. 57(1): 20-24, Jan.
(11) Paper Trade Journal.
1960. Chemicals Used in Paper Making. Vol. 144(2): 46-48, Jan.
(12) Sheist, Irving.
1962. Adhesives, an Economic Study. Speech presented to Mktg. Sec., Amer. Chem. Soc., Atlantic City, N.J., Sept. 9-14.
(13) TAPPI.
1961. Synthetic and Protein Adhesives for Paper Coating. Monogr. Ser. 22.
(14) Trotter, W. K.
1966. The Economic Outlook for Increased Industrial Use of Cereals. Cereal Sci. Today 11(2), Feb.
(15) U.S. Bureau of the Census.
1963. Census of Manufactures. U.S. Gov. Print. Off.
(16) ____
1966. U.S. Imports of Merchandise for Consumption. FT-125. U.S. Gov. Print. Off.
(17) U.S. Department of Agriculture.
1966. Agricultural Statistics. U.S. Gov. Print. Off.
(18) U.S. Tariff Commission.
1945-65. Synthetic Organic Chemicals, U.S. Production and Sales. U.S. Gov. Print. Off.

Meat and Poultry Substitutes

By Herbert H. Moede, George B. Rogers,
Donald B. Agnew, and Lawrence Duewer

Meat and poultry products are sold to consumers in an almost infinite variety of forms. Food processors who use substitutes for meat or poultry ingredients in prepared food products are concerned with (1) competitive raw material costs, (2) comparative flavor, texture, taste, and other performance characteristics, and (3) regulations governing quantities and qualities of food components. Meatlike morsels from soybeans are traditional ingredients in oriental-type foods. Also available to consumers are vegetarian dishes with nonmeat-based imitation chicken, ham, bacon, beef, and other meats.

Development of techniques to concentrate and to fibrillate ("spin") vegetable proteins has led recently to two types of innovations. In one, vegetable protein materials could be used to dilute the meat component of foods such as hamburger, spaghetti sauce, frankfurter, and other comminuted (finely ground) meat ingredients. In the other, vegetable proteins are used to form total meatlike substitutes that simulate texture, flavor, and other characteristics of such products as ham, seafood, chicken, or roast beef.

MARKET SHARE AND CURRENT SITUATION

The three vegetable proteins in the United States with the most potential for the expanding market for meat and poultry substitutes are soybeans, cottonseed, and peanuts. If we disregard peanut butter as a meat substitute, soybeans are the major raw material. But cottonseed flour is used in some bakery products and weight-control beverage foods.

Currently, three general forms of soy proteins are used in foods: (1) Soy flour and grits (50 to 55 percent protein), (2) soy concentrates (over 70 percent protein), and (3) soy isolates, spun or powdered (over 90 percent protein). In most food uses, these proteins serve as binders as well as contributing nutritional values. Federal standards of identity permit soy protein to be used in meat products up to a 3.5 percent level.

The largest human food uses for soy flour and grits are in baked goods such as doughnuts, bread, and snacks, and in flour mixes. Here, the soy products serve a unique purpose rather than competing with other products. The major functions of the soy products in these uses are (1) to enable bakery products to hold more moisture and stay fresh longer and (2) to prevent products from absorbing too much fat during cooking. Their second largest use is with ground or comminuted meats in meat dishes or processed meat products such as hot dogs, hamburger, sausages, meat loaf, stew, and chili. The soy flour and grits act as a binder and absorb and hold natural meat juices during and after cooking. Soy concentrates and isolates also are used in comminuted meats, dairy-type beverages, gravies, and vegetarian and dietary foods. Their functions in these uses are similar to those for soy flour and grits.

Spun protein isolates can be colored, flavored, and textured for use in vegetarian and dietary foods, as simulators of the meat, poultry, and fish usually used in these foods. Textured vegetable protein products are also beinning to be used in prepared stroganoffs, soups, and other processed food products.

Dale Johnson, an industry representative, estimated the following end-uses for soy protein and grits to replace an animal-source raw material in commercial products in August 1967:

Product	Estimated annual quantity (pounds)
Meat products - fresh, smoked, and canned	30,000,000
Pet food	120,000,000
Calf milk replacers	15,000,000
Soy milk and beverage products	10,000,000

Various industry sources estimate that cereal products annually use about 90 million pounds of soy flour and grits.

Kenneth L. Robinson of Cornell University estimates that use of soy protein as a substitute or extender for meat in frankfurters, chili, meat loaf, and some frozen dinners will increase in the next decade. However, these products currently account for only a fraction of 1 percent of comminuted meat sales.

Textured soy protein isolate has a fibrous protein structure and is one of the newer technological advances in this field. The major purpose of spinning the protein into a fiber is to increase palatibility of the end-product in terms of "mouth feel" and to closely simulate natural meat product consistency and appearance. Bland and flavorless when formed, the textured fiber of soy protein isolate can be flavored to simulate a number of meat products. The products are usually called meat analogs.

Meat analogs generally contain a higher percentage of protein per ounce than their natural counterparts. For example, one major processor's analogs contain the following percentages of available protein:

Analog	Protein content of analog (percent)	Protein content of natural product (percent)[1]
Seafood.....	70	[2] 16.7
Ham.....	60	[3] 17.5
Ground beef....	55	[4] 17.9
Bacon bits.....	45	[5] 8.4
Chicken	70	[6] 18.6
Beef.....	60	[7] 16.5

[1] Composition of Foods. U.S. Dept. Agr., Handb. 8, Dec. 1963.
[2] Flounder.
[3] Commercial cured medium fat.
[4] Hamburger regular ground.
[5] Cured.
[6] Fryers ready-to-cook.
[7] Total carcass, U.S. Good grade.

COMPETITIVE EFFECTS

The effects of plant-source protein foods on the markets for meat and on consumption of meats would differ with their uses, their prices compared with prices of meats and poultry, relative total per capita supplies of meats, consumer disposable income, and consumer perferences. The plant-protein foods may become established in various uses as meat extenders, substitutes for nonmeat foods, or meat substitutes.

As meat extenders, plant-source proteins have definite usefulness as an ingredient in certain meats or related foods, whether for texture, binder, taste, or economy. These foods would include sausage, processed meats, and gravies in some precooked meats, for example. In this usage, the plant proteins would supplement rather than supplant the meats. Recent studies show that wieners, sausage, and processed luncheon meats account for about 19 percent of total sales of meats by retail chainstores. Federal and State health laws limit the maximum content of various nonmeat ingredients in processed meats. Assuming 3.5 percent as the maximum allowable limit for plant-source ingredients in processed meats, the total consumption of meat products could be expanded approximately 0.6 percent by extenders. It has been estimated that 30 million pounds of soy proteins are currently used in processed meat products.

Used as substitutes for nonmeat foods, products containing solely plant-based proteins would serve consumer demands where diets are restricted for health or religious reasons. Several large manufacturers have recently developed meat-type foods based on soy protein isolate and spun protein fibers; these can be made with flavor and texture resembling turkey, chicken, ham, and beef. The products are reported to have gained wide acceptance among special consumer groups. In these uses, the plant-based protein foods compete with lentils, cereals, and other nonmeat foods rather than directly with meats themselves.

As meat substitutes, plant-source protein foods would gain additional acceptability, beyond their use as extenders or for dietary purposes, only in direct competition with meats, as alternative products. They would have to appeal to consumers on a suitable cost-and-taste basis, and to retailers on a comparable profit basis.

Consumers' preferences relate to combinations of foods that they purchase. These combinations are affected by relative prices of the various foods available, and by consumers' incomes and tastes. To be widely accepted, new food products must fit consumers' budgets, diets, and tastes. Thus, the price of a new product compared with competing products becomes an important factor in its acceptance by consumers. Since fresh meat cuts are available at retail in a range of prices, a new product could be priced in a range perhaps as high as steaks or as low as hamburgers. The new product might compete poorly with one and rather well with the other.

It seems likely that substitute products for red meats would compete with the higher priced cuts if they had comparable taste and texture and nutritive value, provided they were lower in cost to consumers. Perhaps consumers would purchase the substitute products occasionally when preferred meats might be in seasonally short supply and at seasonally higher prices. Or they might accept them as another possible main dish item for weekday meals, like the moderate-priced meat cuts.

As of November 1967, market prices of soybean products in bulk lots were as follows:

Item	Cents per pound
Soy flour.....	6½-7
Soy grits.....	8 -10
Soy concentrate ..	18
Soy protein isolate.....	35 - 39

By comparison, wholesale prices for selected beef primal cuts in large Eastern cities during winter 1967-68 ranged from 71 to 74 cents per pound for sirloins, 52 to 54 cents per pound for rounds, and 36 to 40 cents per pound for beef arm chucks.

Prices for spun protein fiber products are considerably higher. On a dry weight basis, the price for spun protein is about $1 per pound, according to D. L. Call of Cornell University.

Wholesale price represents costs to final processors or retailers. Degrees of processing and packaging differ, and both final retail prices and the retailers' margin would differ.

The textured meat-type products made from soy protein isolate currently available would probably need to be priced at retail near the upper range of prices for red meat. These products are reported to have a relatively high ingredient and production cost, and adding usual marketing markups would result in retail prices that might range as high as those for steaks and other cuts from sirloins. At somewhat lesser production costs or marketing margins, retail prices for the meat substitutes might range nearer those for meat cuts from beef rounds. It is likely that prices could not be reduced to levels comparable with lower priced beef cuts, such as chuck, unless much larger production can be achieved at correspondingly lower cost.

The general levels of prices, which might be considered to represent retail-price thresholds which the new substitute product could expect to compete with in the market, are shown in table 1 for beef and in tables 2 and 3 for poultry. Competition is assumed here for selected cuts of fresh meats and for processed poultry. Under an alternative set of assumptions, we can derive the minimum retailers' margin thresholds at which the new products might enjoy the interest of retailers as a product to merchandise. It is assumed that meat substitutes would need to generate profits comparable to those of the fresh meats or the processed poultry. One approach to the situation is to assume comparable retail prices to consumers and comparable costs into the case, taking into account the differences in store labor cost and trimming loss for meats and for meat substitutes. (Because of losses in bone and fats in cutting meats for the retail case, a comparable cost-into-case for beef would represent storedoor cost, plus labor and packaging cost, adjusted to represent equivalent retail weight rather than delivered weight.)

In view of the relatively low cost of soy protein compared with fresh meat and poultry, it would be logical to expect some competitive inroads by the substitute products. How might the synthetic product affect retail margins for meats or poultry if priced competitively? What might be the upper limit of retail prices at which the synthetic product could initially compete effectively with the natural products? These aspects of price and profit may be considered as possible economic thresholds for the substitute products to gain a market foothold.

Both meat and poultry present special problems in determining into-store costs. For example, we cannot take a retail cut of meat and construct an equivalent into-store weight and equivalent cost because carcass meat is often processed into retail cuts at the store. A similar situation exists in terms of into-plant costs for poultry.

In table 1, ranges of retail prices per pound for selected beef cuts are presented along with composite sales value, wholesale cost, and cutting loss and waste. From these figures we can derive equivalent estimated margins and prices. Typical cost and markup for selected processed poultry products are shown in table 2.

An important factor in the acceptance of substitute meats in the market would be their profitability to retailers compared with that of meats. What margins might a synthetic product yield when priced competitively with the fresh meat product? The reluctance of retailers to incur large

Table 1.--Range in retail price per pound for selected beef cuts and composite sales value, wholesale cost, and cutting loss and waste, for selected retail chainstores, 3 eastern cities, for 1 week, winter 1967-68

Item	Beef sirloins	Beef rounds	Beef arm chucks
		Dollars	
Range in retail price per pound, typical cuts[1]	1.23 - 1.55	1.07 - 1.39	0.59 - 0.95
Composite retail value per pound[2]	1.22 - 1.32	1.00 - 1.08	.71 - .75
Composite wholesale cost per pound[3]	.71 - .74	.52 - .54	.36 - .40
		Percent	
Range in losses--fat, bones, shrink	15 - 26	22 - 27	19 - 29

[1] Typical retail cuts in wholesale primals are for sirloin: Sirloin tip, sirloin bone in, porterhouse and for rounds: Round steak, sirloin steak, round bone in, cube steak, round top, round bottom, round heel, eye round, rump bone out and for chucks: Arm roast, blade roast, English cut boneless, 7-bone roast, short rib bone in, stew beef, shin or shanks (bone in), cross rib roast, ground beef.

[2] Weighted average price for all sales, retail weight basis.

[3] Cost per pound, wholesale weight basis, for the primal cut. Difference between composite retail value and wholesale cost is gross margin on materials before deducting costs for cutting, pricing, selling, and overhead.

Source: Unpublished ERS study.

increased fixed costs for additional freezer-case space, or to accept narrower margins on frozen meats than on fresh meats, is reported to have contributed to the lack of acceptance of frozen meats among retailers about 15 years ago. This situation meant higher retail prices for frozen meats than for competing fresh meats, which in turn contributed to lack of consumer interest. Hence, the importance of comparative margins to retailers in introducing new products. Retailers could make as much profit from the substitute products as from fresh meats at identical retail prices per pound, even at somewhat higher storedoor cost for the substitute products, provided the difference in storedoor cost or cost-into-the-retail-case between fresh meat and substitutes reflected only differences in net salable weight--i.e., was sufficient only to cover differences in the loss in handling at retail due to shrink, waste, and trim loss--and differences in handling cost at retail.

In brief, a storedoor cost of 90 cents per pound for a major primal cut of beef that would incur a 16-percent trim loss would be comparable with a cost of $1.05 per pound for a synthetic product already packaged and subject to no shrinkage loss. Assuming identical selling prices--$1.25 per pound, for example--a synthetic item costing the retailers $1.05 per pound could yield a margin of 20 cents per pound, and the beef costing 90 cents per pound as a primal cut (equivalent to $1.05 retail weight basis) would yield the same markup but a smaller net margin because of costs for cutting and packaging at the retail store.

The third line in table 1 presents composite wholesale costs per pound of specified cuts to the retailer. By using the estimated primal cut loss data for fat, bones, and shrinkage shown in line 4, composite wholesale cost per pound can be adjusted upward to obtain an estimated maximum comparative cost to the retailer at which a meat analog of presumed excellent taste and quality could be expected to compete on a purely price basis. For example, to estimate comparable prices to the retailer for meats and substitutes, we adjust price for each primal cut upward by about 20 percent for sirloins and 25 percent for rounds and chucks to provide an estimated into-store cost per pound of 80 cents for sirloins, 65 cents for rounds, and 50 cents for chucks. (The percentage adjusters represent the approximate midpoint of the range in cutting losses for those products in line 4.) Thus, meat analogs, to be competitive with meats as profit items, would

Table 2.--Derivation of estimated boned meat cost for selected end-products

End-product	Meat cost	Estimated direct boning costs[1]	Boned meat costs	End-product weight	Meat content	Proportion of meat in end-product	Value of meat in end-product
	Cents per pound	Cents per pound	Cents per pound	Ounces	Ounces	Percent	Cents
Turkey roast.....	58.33	4.67	63.00	16.00	16.00	100.000	63.00
Turkey TV dinners....	75.00	5.00	80.00	11.00	2.20	20.000	11.00
Turkey pot pies.....	75.00	5.00	80.00	8.00	1.25	15.625	6.25
Canned chicken soup..	45.00	8.00	53.00	10.50	.42	4.000	1.39
Canned boned chicken.	45.00	8.00	53.00	5.00	4.25	85.000	14.07
Chicken pot pies.....	45.00	8.00	53.00	8.00	1.25	15.625	4.14

[1] Labor, equipment, power

Table 3.--Estimated plant's delivered selling prices and retail chainstore prices for selected end-products

End-product	End-product weight	Value of meat in end-product	Other costs and markups	Plant's delivered selling prices	Retail selling price	Retail margin	Ratio of retail markup to retail cost
	Ounces	Cents	Cents	Cents	Cents	Cents	Ratio
Turkey roasts.....	16.00	63.00	17.00	80.00	112.00	32.00	1.400
Turkey TV dinners....	11.00	11.00	22.69	33.69	42.00	8.31	1.247
Turkey pot pies.....	8.00	6.25	11.37	17.62	22.00	4.38	1.249
Canned chicken soup..	10.50	1.39	11.61	13.00	17.00	4.00	1.308
Canned boned chicken.	5.00	14.07	15.93	30.00	36.00	6.00	1.200
Chicken pot pies.....	8.00	4.14	14.10	18.24	22.00	3.76	1.206

have to be priced to the retailer at about these same levels. In reality, they could possibly be slightly higher but under no circumstances could the retailers' cost for synthetic items exceed the basic cost for fresh meats, plus cutting and packaging costs, without yielding a lower retailer net margin for the synthetic replacement than the margin obtained for fresh meats.

The second line of the table shows the composite retail values per pound for a mix of various priced cuts obtained from the designated primal meat cuts. Using the same procedure as above, it appears that the synthetic product would experience difficulty in competing with sirloin cuts if the synthetics were retailed at a price exceeding $1.25 per pound; with round cuts, at a price above approximately $1 per pound; and with chuck cuts, above 70 cents per pound.

Tables 2 and 3 present comparable data for selected turkey and chicken products. The situation for these products is similar to that for the red meat items. That is, the cost of the synthetic product to the retailer cannot exceed fresh poultry meat costs plus boning costs (about 80 cents per pound cost to the retailer to compete with turkey roasts). Nor could the synthetic product

provide a lower margin than the fresh product to compete successfully in the market. Here, the competitive cost of ingredients for the processor ranges from 58 to 75 cents per pound for poultry; the retailer's cost for a completely packaged turkey roast, at 80 cents per pound, is near the average price for all cuts from sirloin (80 cents) and above that of cuts from beef rounds (65 cents). A synthetic product might be priced to generate more retailer profit than moderate-priced beef cuts from the round, or lower priced turkey items such as TV dinners. However, it might encounter consumer resistance if priced at the same level as turkey roasts or cuts from the sirloin.

While it appears that the present cost of soy protein is low enough to be advantageous in some uses, its current prices may be too high for it to successfully substitute for highly preferred meats in the immediate future.

Soy proteins in the immediate future should be regarded as competing with meat for manufacturing, not prime cuts such as beef loins or rounds. Recent prices quoted for the Chicago market indicate that meat for boning sold for 34 to 35 cents per pound, regular sausage trimmings for $24\frac{1}{2}$ cents, and 50-percent lean trimmings for $26\frac{1}{2}$ cents. At the same time, skinless franks in vacuum-packed 1-pound packages sold for 54 cents. These costs are quoted to show the general price realm into which costs for soy proteins must be placed.

The greatest future for soy proteins in meatlike products seems to be in the institutional market. Here, specially flavored ham or baconlike particles for use in scrambled eggs, meatlike ingredients for soups and stews, and simulated luncheon meats could well compete with meat products. The present retail price of baconlike granules for inclusion in scrambled eggs is $2.83 per pound. Conceivably, this product could be sold at a lower cost on a volume basis; it already provides cheaper protein than natural bacon.

It must also be recognized that substitute meat products provide a chemically different sort of food with fewer calories per pound than meat.

A retail simulated luncheon meat contains 6.8 percent carbohydrate while genuine luncheon meats seldom exceed 1.5 percent. All-meat frankfurters contain about 340 calories per 100 grams, the simulated product about 100 calories less. This could be readily changed by incorporating more fat in the products. In fact, one potential advantage of simulated meat products is the ease of varying the chemical composition.

Textured soy protein which is used where a meatlike mouth feel is important must be distinguished from soy flour which is used as an extender or diluent in comminuted meat products.

One diet food processor has recently sold a small quantity of its spun soy products at $1.46 pound (wet weight). The analyzed composition was as follows:

	Chicken	Beef	Luncheon meat
Percent protein.....	21.4	21.3	23.5
Percent fat	18.5	10.4	15.2
Percent carbohydrate.	2.7	5.5	6.8

Another diet food processor recently test-marketed imitation bacon and Western-style mixes of textured soy flour with flavors, etc., for scrambled eggs. A spice and flavoring processor has introduced nationally a hot dog seasoning mix based on soy. These products were rated by an independent laboratory as having the texture and mouth feel of meat.

Thus, textured soy protein is making rapid strides in formulated foods, and the market in schools and institutions may be invaded soon. The extent of market penetration is difficult to predict now. The competition is with the lowest valued meat byproducts of the chop, steak, and roast market. In poultry products, the competition is with fowl (culled laying hens) which are also inexpensive.

TECHNOLOGICAL FACTORS AFFECTING DEVELOPMENT OF MEAT SUBSTITUTES

Advances in the technology of the processing of soy protein combined with increased knowledge of flavors may at some time in the future cause a complete reversal of the situation previously described. If these changes and developments should take place, there might be some loss of market by the meat and poultry segment of agriculture and increased demand for products from another agriculture area--specifically soybean growers. This shift in demand, since it could result in a larger demand for food protein obtained from soy meal, would possibly create disposal problems for the additional quantities of soybean oil that would become available.

SUMMARY

Three general forms of soy proteins are used in foods: Soy flour and grits, soy concentrates, and soy isolates. Each of these forms may be used as a component in the formulation of comminuted meat, health, and diet food products. Most food uses of these proteins are for functional as well as nutritional purposes. Federal standards of identity limit the level of use in comminuted meat products, and meat analog products must be labeled as to composition. As yet, it is too early to evaluate the complete impact these synthetic products will have on the meat and poultry market, which may be the largest potential food market for soy protein.

Sugar Substitutes

By Roy A. Ballinger

The ordinary sugar of everyday commerce is sucrose obtained from sugarcane or sugarbeets. In practice it includes a certain amount of invert which is derived from sucrose by simple chemical means. Invert consists of a mixture of dextrose and levulose formed when the disaccharide sucrose is reduced to two monosaccharides by hydrolysis. Invert or a mixture of invert and sucrose is preferred by industrial food processors for certain uses. While nearly all the world's supply of sugar is obtained from sugarcane or sugarbeets, it is technically possible to obtain sugar from a wide variety of plants. Attempts to do this on a commercial scale, if successful, will affect the market for sugar derived from cane or beets. The probable economic effects, particularly on sugarcane and sugarbeet growers, of two such potential sources are examined.

TYPES OF SUBSTITUTES

The two most important commercial characteristics of sugar (sucrose) are sweetness and nutritive content. All sugar substitutes are sweet to some degree. Some have nutritive value, primarily in the form of calories, and others are nonnutritive.

Caloric Sweeteners

The most important nutritive sweeteners, other than sugar itself, are those derived from starch. They are commonly called corn sirup and dextrose. In the United States, they are manufactured mostly from cornstarch, although starch from grain sorghum is used to some extent.

Starch is a polymer which can readily be reduced to simpler substances. If this process of hydrolysis is carried out completely, the end-product is dextrose, which forms one-half of invert sugar. If the process is stopped before completion, a mixture of dextrose and other saccharides, but no sucrose, is obtained. The composition of this mixture can be controlled to a considerable extent by the manufacturer and a variety of sirups are marketed. Neither corn sirup nor dextrose is as sweet as sugar.

The starch sweeteners are less sweet than sugar, but they have important commercial attributes other than sweetness and are employed in some uses partly because they are less sweet than sugar. Consequently, quantity comparisons between sugar and the starch sweeteners are made on a dry weight basis.

Levulose is another caloric sweetener of potential importance as a competitor of sugar (sucrose). In addition to the levulose that constitutes half of invert sugar, small quantities are now being produced in other ways. Levulose is considerably sweeter than sucrose. It can be obtained from certain plant sources by separating the levulose and dextrose which constitute invert sugar and by the chemical conversion of dextrose to levulose.

A company in Hawaii which also produces sugar from sugarcane reports the production of 3 or 4 tons of levulose per month from the tuber of the ti plant. Ti is a shrub native to Hawaii. This company sells its levulose to pharmaceutical companies. It reports that the cost of production is too high to permit sale of the product for food purposes.

Present methods of obtaining levulose from invert sugar by separating it from the dextrose also appear to be expensive and comparatively little is produced. Reliable data are not available.

Biochemical means of converting dextrose into levulose have been known for some years. The process has been considered too expensive to be used commercially. However, since late in 1967 a producer of corn sirup and dextrose has been marketing a product manufactured from dextrose which contains about 15 percent levulose. It is manufactured by

an enzyme process. The company reports plans to market sirups containing up to 50 percent levulose at some future date. The sirup is being sold to food processors and appears to be of considerable potential importance, although the current volume of sales is too small to have any significant market effect.

A small amount of lactose (milk sugar) is produced in the United States and is used for various specialty purposes. The principal point at which it competes with sugar is as an ingredient of certain mixtures containing lactose and some synthetic sweeteners. One or two companies offer such mixtures for sale, claiming that they are as sweet as sugar but contain fewer calories, usually about half as many per pound. The product is usually prepared in such a form that a spoonful has about the same sweetening power as a spoonful of sugar. Apparently, sales of these products to date have been quite small and they have had little impact on sugar sales.

There are also certain caloric sweeteners which have been in use at least as long as sugar. These include honey, maple sirup, sorghum molasses, cane sirup, and edible cane molasses. With the exception of honey, all these have been slowly declining in importance in the United States. The per capita consumption of honey has remained relatively stable. All of these products compete in some degree with sugar, although they are not often thought of as sugar substitutes. Total per capita consumption of these products is slightly in excess of 2 pounds per year. Honey accounts for more than half of this. Annual per capita consumption of sugar averages about 97 pounds.

Noncaloric Sweeteners

The two noncaloric sweeteners of commercial importance in the United States are saccharin and cyclamate. Neither has any nutritive property. Both are manufactured from nonagricultural materials. Saccharin has been produced since about 1900 and cyclamate since 1950. Since around 1960, sales of mixtures of saccharin and cyclamate have become important. The sweetness of such mixtures is additive; that is, equal to the sum of the sweetness of each ingredient. Certain undesirable tastes in each ingredient are not additive, and since less saccharin and less cyclamate are needed in the mixtures to produce a given level of sweetness, objectionable flavors are less noticeable when mixtures are used.

The relative importance of noncaloric sweeteners can best be judged in terms of their sweetness compared with that of sugar. Sweetness is almost the sole economic attribute of saccharin, cyclamate, or mixtures of these. As a general rule, saccharin is considered about 300 times as sweet as sugar and cyclamate 30 times as sweet. There are wide variations in these ratios, depending on the product in which they are used and the individual consuming them.

A number of other synthetic substances are known which also are much sweeter than sugar. None have been approved for use in food products in the United States. One such product, dulcin, is used to some extent in certain other countries.

USDA's Agricultural Research Service has discovered three dihydrochalcones which can be manufactured from flavonoids present in citrus waste and are intensely sweet, two about 150 times as sweet as sugar and the third 2,000 times as sweet. These substances are not now being produced or marketed commercially, although they are being tested for their suitability for use in food products. Such use has not yet been approved by the Food and Drug Administration. The substances are reported to have no objectionable flavors. The onset of sweetness is relatively slow but lasts longer than that of sugar.

If any of these dihydrochalcones should become important commercially, they might compete more directly with saccharin and cyclamate than with sugar, either in the form of mixtures with these substances or as the sole sweetening agent. Some competition with sugar is also likely, although its extent cannot be measured at the present time.

Maltol, a substance which increases the sweetness of sugar when used in the preparation of certain foods, is being marketed by two chemical companies. It is reported to enhance the flavor of all carbohydrates, including sugar. Sales of maltol appear to have been small and to have had little effect on the sugar market, although figures are not available.

Ammoniated glycyrrhizin, a product prepared from licorice, also is sometimes used as a flavor enhancer. The only known producer in the United States has stated that it "is 100 percent sweeter than sucrose in the presence of sucrose." The product is not recommended by the producer for use in all foods because of an

undesirable flavor it imparts to certain products. Production or sales figures are not available, but no effect on the sugar market has been observed.

New Sources of Sucrose

With minor exceptions the world's supply of sugar (sucrose) has always been obtained from sugarcane and sugarbeets. Until the early 19th century, it all came from sugarcane. However, nearly all plants at some time during their growth contain sucrose. Generally, obtaining sugar from sources other than sugarcane and sugarbeets has been too expensive to be commercially practicable.

Efforts to obtain sucrose from sweet sorghums on a commercial basis have been made periodically in the United States since the middle of the 19th century. The earlier efforts all failed for various reasons, such as inability to remove from the sorghum juice certain impurities which interfered with the crystallization of the sugar, low yields of sugar per acre, and an uneconomically short grinding season. Many of these difficulties seem to have been largely overcome and there is currently considerable interest in the commercial production of sugar from sorghum.

Within the last 2 or 3 years, one company has been attempting to produce sucrose, or a mixture of sucrose and invert, commercially from cornstalks. This is being attempted using varieties of corn which produce either very few ears or ears with very few kernels. The lack of kernels is accompanied by a much higher sucrose content in the stalk than normally occurs in corn.

A trade report indicates that this company contracted with farmers to produce 400 acres in 1966 and 11,000 acres in 1967, and it plans to further increase acreage in 1968. The company has two plants, one about 10 miles west of Fargo, N. Dak. and the other at Waseca, Minn. A sirup, prepared from the juice in the cornstalks, contains sucrose and invert sugar in varying proportions. The sirup is reported to be suitable for use in manufacturing practically all food products, except soft drinks. The mineral content at present is too high for use in most soft drinks.

Not enough information is currently available to permit a reasonably accurate estimate of the yield of sugar solids per acre from cornstalks. However, if it should average 1 ton per acre, dry basis (an outturn much lower than is obtained from either sugarbeets or sugarcane), 50,000 acres would produce 50,000 tons of sugar--about 0.5 percent of total sugar consumption in the United States.

Research on Sweeteners

A considerable amount of research directed toward the discovery of new sweeteners, or the improvement of existing sweeteners, mostly by private firms, appears to be in progress. An attempt to determine the chemical and physiological factors controlling taste, for which some progress reports have been published, has considerable long-range interest. At the present time, no one knows exactly why sugar or any other product tastes sweet. However, it is reported that a specific protein has been isolated from that part of the tongue of cattle and hogs sensitive to the taste of sweetness, which reacts with both sugar and saccharin. The reaction with saccharin is about 300 times as strong as that with sugar, approximately their ratio of sweetness. Basic knowledge concerning the chemistry of sweetness may well facilitate the discovery of new, useful sweeteners.

THE U.S. SUGAR QUOTA SYSTEM

Since 1934, sugar in the United States has been produced, imported, and marketed under a quota system. Although the original Act of 1934 has been revised numerous times and many changes in detail have been made, the basic concept and means of control have not been altered. The law directs the Secretary of Agriculture to determine for each calendar year the sugar consumption requirements of the United States. It provides the Secretary with only general guidance for determining consumption requirements: "Determinations shall be made so as to protect the welfare of consumers and of those engaged in the domestic sugar industry by providing such supply of sugar as will be consumed at prices which will not be excessive to consumers and which will fairly and equitably maintain and protect the welfare of the domestic sugar industry." The Secretary, however, is authorized to make such changes in his determination of consumption requirements during any year as he deems necessary.

The law also specifies the formula to be used by the Secretary in dividing the consumption requirements among the various domestic areas and foreign countries.

In administering the Sugar Act, the Secretary exercises considerable influence over sugar prices and indirectly over the prices of other sweeteners.

TRENDS IN THE USE OF SUGAR AND OTHER SWEETENERS

The total consumption of sugar, corn sweeteners, and noncaloric sweeteners in the United States in 1957 amounted to about 9,200,000 tons; by 1967 it had increased to 11,900,000 tons (table 1). During this period, the proportion of total sweetener consumption supplied by sugar declined about 7 percentage points, while that coming from corn sweeteners increased 3 points and the share of noncaloric sweeteners rose 4 points. Sugar, however, still accounted for nearly 79 percent of the total in 1967. Also, per capita consumption of sugar has remained relatively unchanged but per capita consumption of other sweeteners has increased.

All but minor amounts of each class of sweeteners are used in food and beverages. However, the distribution among types of food products is quite different for the different sweeteners. About half of the dextrose consumed in the United States is used in the baking industry, primarily to aid fermentation in products manufactured with yeast.

Most of the dextrose used in nonfood industries also is used in some type of fermentation process. Nearly one-third of the corn sirup distributed in the United States is used in the confectionery industry, although the proportion used there has been declining while usage in the canning, dairy, and baking industries have increased considerably since 1957.

The beverage industry is the largest industrial user of sugar. Also, the proportion delivered to this industry has increased considerably since 1957. This increase reflects primarily the rapid growth in output of the soft drink industry. It has occurred at the same time as the growth in the volume of production of soft drinks sweetened with noncaloric substances.

The consumption of both the starch and the noncaloric sweeteners is subject to certain regulations of the Food and Drug Administration which in some way restrict the quantities used. In the canning industry, corn sirup or dextrose frequently is mixed with sugar and the blend is used to sweeten the product. The Food and Drug Administration has established maximum proportions of these sweeteners which can be used in a mixture with sugar for various canned

Table 1.--Estimated consumption of sweeteners in the United States, 1957-67

Years	Sugar[1]	Corn sweeteners[1]	Noncaloric sweeteners[2]	Total
	1,000 tons			
1957	7,950	1,044	225	9,219
1958	8,210	1,165	230	9,575
1959	8,336	1,208	235	9,779
1960	8,423	1,238	240	9,901
1961	8,775	1,273	250	10,298
1962	8,881	1,397	275	10,553
1963	9,136	1,520	453	11,109
1964	8,839	1,636	646	11,121
1965	9,183	1,654	659	11,496
1966	9,523	1,719	712	11,954
1967[3]	9,488	1,695	750	11,933

[1] Dry weight.
[2] Equivalent sweetness, saccharin 300 and cyclamate 30 times as sweet as sugar.
[3] Preliminary.

fruits. Many canners are now using the maximum amount of corn sirup or dextrose permitted by the regulations, and indicate that they would use more if permitted.

Products sweetened with noncaloric substances must have the name of each substance printed on the label. Moreover, the label must include a statement to the effect that the substance is an artificial sweetener for use by those who desire to restrict their intake of ordinary sweeteners. The effect of this labeling on the consumption of noncaloric sweeteners has not been measured, although it seems more likely to have reduced than increased their use.

Food and Drug Regulations do not provide for the sale of products sweetened with a mixture of noncaloric sweeteners and sugar, and such products are not sold in the United States. If the sale of products sweetened with mixtures of sugar and noncaloric sweeteners were permitted, the use of noncaloric sweeteners would logically be expected to increase somewhat. However, judging from the experience of countries such as England, where the sale of such products is permitted, the effect might not be very large.

SUBSTITUTION AND ADDITIVE EFFECTS OF NONSUGAR SWEETENERS

Corn Sweeteners

While much of the corn sweeteners used in the United States has undoubtedly replaced sugar, there are certain uses where these substances appear to improve the quality of the product manufactured and, therefore, serve primarily to increase the total quantity of caloric sweeteners used in this country. Perhaps the best example of this is the use of corn sirup in the manufacture of hard candies. It is difficult and relatively expensive to manufacture good quality hard candy without using 40 percent or more of corn sirup in the raw material. Without corn sirup, or some satisfactory substitute for it, the production of hard candies might be considerably smaller than the present output. However, there is doubtless some substitution of corn sirup for sugar with hard candies, because the proportion of corn sirup in the mixture can be varied somewhat without materially affecting the quality of the product.

In other cases, such as in the use of dextrose in baking, the major effect appears to be the substitution of dextrose for sugar, since they work about equally well in products made with yeast, where the function of the sweetener is to promote fermentation. In other cases, such as in ice cream where the dextrose or corn sirup has some effect in improving quality but is not essential, the effect of their use is divided in some unknown proportion between displacing sugar and enlarging the market for caloric sweeteners.

Corn sirup or dextrose is used in combination with sugar as the sweetening agent in many other products. The relative prices of these sweeteners sometimes affect the proportions used. Prices of dextrose and corn sirup have declined somewhat relative to those for sugar since 1957, the decline being much more marked for corn sirup than for dextrose (table 2).

The downward trend in the price of corn sirup relative to sugar has been accompanied by a rapid increase in the quantity of corn sirup sold (table 2). The increase in sales of dextrose was more moderate, as was the relative decline in the price of dextrose. Most of the increased use of corn sirup has been in the canning, dairy, and baking industries. It is not feasible to determine the extent to which these changes are the result of price changes or of other factors, such as changes in consumer preference, improvement in quality (particularly in corn sirup), and development of new techniques in the canning, dairy, and baking industries. A University of California study indicates that relative price changes among caloric sweeteners have a significant influence on the quantities used in various industries.[1]

A change in the sweetener mixture usually involves certain other adjustments in formulas or plant operations. It may also involve some change in the final product, which may be apparent to some consumers. In such cases, increased advertising or promotion may be necessary to maintain sales.

Such changes always cost something and are made only when long-term benefits are anticipated.

Noncaloric Sweeteners

Until about 1950, saccharin was the only noncaloric sweetener used in the

[1] Marvin Lee Hayenga. Sweetener Substitution in Food Processing Industries. University Microfilms, Ann Arbor, Mich., 1967.

Table 2.--Prices of dextrose, corn sirup, and refined sugar, 1957-67

Year	Sugar[1]	Dextrose[2]	Corn sirup[2]	Dextrose relative to sugar	Corn sirup relative to sugar
	Cents per pound	Cents per pound	Cents per pound	Percent	Percent
1957.....	9.15	8.32	9.17	90.9	100.2
1958.....	9.27	8.33	9.18	89.9	99.0
1959.....	9.33	8.13	9.10	87.1	97.5
1960.....	9.43	8.13	9.12	86.2	96.7
1961.....	9.40	8.10	9.00	86.2	95.7
1962.....	9.60	8.04	8.73	83.8	90.9
1963.....	11.94	9.10	9.19	76.2	77.0
1964.....	10.68	8.85	8.36	82.9	78.3
1965.....	10.22	8.70	8.27	85.1	80.9
1966.....	10.36	8.87	8.34	85.6	80.5
1967.....	10.62	9.10	8.40	85.7	79.1

[1] Refined, wholesale, New York.
[2] Dry basis, wholesale, New York.

United States. It was used largely by people who, for health reasons, were not supposed to eat sugar. Under these circumstances, the sales of saccharin hardly had any effect on the sugar market. This was also true of sales of cyclamate for a number of years after it was first marketed.

However, after the introduction of mixtures of saccharin and cyclamate about 1960, sales of these products increased rapidly and, by 1963, had become a matter of considerable concern to the sugar industry. After 1965, the rate of expansion in the use of these products appears to have declined, although the consumption of saccharin and cyclamate still seems to be growing more rapidly than that of sugar. Even so, most of the saccharin and cyclamate consumed in the United States still seems to be used by people who would not have used sugar in any event. Only one-fourth to one-third of the sales of saccharin and cyclamate appears to have replaced sugar, the remainder serving to increase the size of the sweetener market.[2]

The upward trend in the use of saccharin and cyclamate appears likely to continue, possibly at about the rate prevailing since 1964. Soft drinks are likely to continue to be the principal products sweetened with these products. Generally, soft drinks can be sweetened with noncaloric substances more satisfactorily than most other products because fewer changes are needed in the other constituents of the product.

Based on trade estimates, the use of noncaloric sweeteners in soft drinks in 1970 will be about double that of 1965. If the consumption of noncaloric sweeteners in uses other than soft drinks increases only at the same rate as the projected population increase, total consumption of these products in 1970 would be about 21 million pounds of cyclamate and 4 million pounds of saccharin. This is equivalent in sweetness to about 915,000 tons of refined sugar. Substitution for sugar is likely to amount to between 250,000 and 350,000 tons. This is about 3 percent of probable sugar consumption in 1970.

At the present time, both saccharin and cyclamate are much cheaper than sugar per unit of sweetness. There has been a major decline in the price of cyclamate since 1963. A mixture of 10 parts cyclamate and 1 part saccharin, equivalent in sweetness to 1 pound of sugar, now costs about 1.4 cents compared with 10.6 cents for sugar. However, the price of noncaloric sweeteners appears to be much less important than the price of corn sweeteners in determining the quantities used. Many

[2] Roy A. Ballinger. Noncaloric Sweeteners: Their Position in the Sweetener Industry. U.S. Dept. Agr., Agr. Econ. Rpt. 113, May 1967.

persons are not aware of the presence of corn sweeteners in products they buy but they nearly always recognize the presence of noncaloric sweeteners. Also, the lower price for noncaloric sweeteners is in some cases more than offset by increases in other costs. For instance, in canning peaches sweetened with noncaloric substances, it is necessary to use fruit of higher quality to obtain a product the consumer will buy than is needed when sugar is used. Consequently, the processor's cost of a can of peaches sweetened with saccharin and cyclamate may be higher than the cost of a can sweetened with sugar.

MEETING THE COMPETITION OF SUGAR SUBSTITUTES

There are three general ways in which the competition of nonsugar sweeteners might be at least partially met. One method is by Government regulation. Sugar in the United States is produced, imported, and marketed under a quota system. This system in effect determines the size of the market for sugar in this country each year, and divides this market among producing areas, dometic and foreign. If necessary, the quota for each domestic area is also divided among individual sugarcane and sugarbeet growers. Market supplies of sugar have been regulated so that the price of sugar in the United States is considerably higher than in the so-called world sugar market.

At various times it has been suggested that it might be possible to devise some system which would regulate the production and sale of the corn sweeteners and the noncaloric sweeteners so as to limit or prevent their use as sugar substitutes. However, it is doubtful if such regulation is feasible. Only a small part of the corn produced in the United States is used for the production of corn sirup and dextrose. The size of the corn crop as a whole is influenced by Government regulation but the shares used for various purposes are not regulated and it probably would be difficult to regulate them effectively, especially if corn growers and processors were opposed.

Regulation of the sale of noncaloric sweeteners at present is largely confined to matters related to health. While this has the incidental effect of restricting their use in certain ways, the imposition of any overall quota or quantity limitation would require an entirely different type of regulation. Such a regulation might be even more difficult to enforce for noncaloric sweeteners than for the corn sweeteners. Doubtless producers of noncaloric sweeteners would object to regulation intended to benefit another industry.

Another method of meeting competition might be with lower prices for sugar. This method probably would reduce somewhat the effectiveness with which the corn sweeteners compete in some food industries, but would not be likely to reduce the sales of noncaloric sweeteners. However, lower prices for sugar would mean lower prices for sugarbeets and sugarcane, which growers might find more objectionable than the present situation.

The third method of meeting competition is to find new uses for sugar. The sugar industry has made considerable effort since World War II to discover new uses for sugar and for products manufactured from sugar. However, these research and promotional efforts have not yet produced anything of much commercial importance. The new products receiving the most publicity have been sucrose esters which have certain desirable characteristics as detergents. They appear to be more expensive to produce than the detergents commonly in use and consequently have not been sold except on an experimental basis.

SUMMARY

The starch sweeteners (corn sirup and dextrose) are currently the most important sugar substitutes in the United States and seem likely to retain that position. One or both of these products are used extensively in all manufactured food products where sweetening is important. Their use in beverages is minor but has been increasing in recent years. In many uses, corn sirup or dextrose is mixed with liquid sugar, and relative prices of the corn sweetener and sugar influence the proportions used.

The recent development of a commercial corn sirup containing various proportions of levulose may increase the extent of substitution of corn sweeteners for sugar. Levulose is sweeter than sugar, whereas dextrose and ordinary corn sirup are considerably less sweet than sugar.

The use of noncaloric sweeteners, primarily saccharin and cyclamate, has increased rapidly in the United States in the past decade. Even so, noncaloric sweeteners remain less important in total volume than

the starch sweeteners. The largest growth in use of noncaloric sweeteners has been in soft drinks.

Many people who consume soft drinks or other products sweetened with noncaloric substances apparently do so for health reasons or as a weight control measure. Therefore, the market for noncaloric sweeteners appears to be partly, but not entirely, differentiated from the market for sugar. Price competition is relatively unimportant.

Intensely sweet substances obtained from citrus waste may become an important sugar substitute in the future. However, these substances, which belong to the dihydrochalcone group of chemicals, have not yet been approved for use in food products by the Food and Drug Administration and are not commercially available at the present time.

In spite of the substitute sweeteners actually or potentially on the market, sugar continues to be by far the most important sweetener in use in the United States or elsewhere in the world. While further substitution of other sweeteners for sugar in the United States seems probable, the market for sugar in this country seems likely to continue to grow, although the growth will be less than if the substitutes were not available. Also, the market for sugar obtained from sugarcane or sugarbeets is likely to be further restricted by sugar obtained from new plant sources, especially sorghum and cornstalks.

Substitutes for Leather

By John W. Thompson

CURRENT SITUATION

Leather is used principally in footwear but also in handbags, gloves, apparel, accessories, upholstery, industrial belting, and novelties. Leather in these uses comes mainly from cattle hides, although a relatively small proportion of calfskins and pigskins is also used. Manmade substitute materials account for about three-fourths of shoe soles and a higher proportion of shoe heels, and have recently started replacing leather materials in shoe liners and shoe uppers. Since plastics have already captured a substantial portion of the market in upholstery, luggage, and handbags, and have made serious inroads into industrial belting, the adoption of new materials for shoe uppers can have serious effects on the market for leather and the U.S. hide and tanning industries.

NATURE OF SUBSTITUTES

There are three primary types of substitute raw materials for shoe-upper leather: Poromerics, vinyl or sheet plastics, and fabrics. From these, 69 leather substitutes have been commercially developed. Seventeen of these materials are competitive in price, and some have properties superior to leather with respect to weight, moisture and abrasion resistance, and permanent gloss. Poromerics and other similar substitute materials are estimated to have gained 5 percent of the side-upper leather market since 1966.

TRENDS IN HIDE PRODUCTION AND USE

Leather is the main and the most profitable outlet for hides. The production of hides is closely related to livestock slaughter. Domestic cattle slaughter yielded 35 million hides in 1967. An additional 2 million hides came from dead or condemned animals. Since 1952, the domestic tanning industry has consumed about 22 million cattle hides annually; the remainder has been exported. A breakdown of the 23 million cattle hides used in 1965 indicates 4 million pieces (17.4 percent) were used in sole leather; 3 million (13 percent) for belting, strapping, gloves, etc.; and 16 million (69.6 percent) as shoe-upper material. The first two uses appear to have leveled off since 1958 and are not expected to change appreciably. However, a significant decline is expected in the number of hides used as shoe-upper material (table 1).

The shoe market is the major outlet for cattle hide leather. Yet, production of shoe leather has not shared the increase in shoe production. The use of leather soling declined precipitously in the late 1940's and leveled off in the 1960's with less than 25 percent of the shoes being made with leather soles. Leather uppers are now suffering from competition by synthetic poromerics and other substitutes and are likely to fall off appreciably in the near future. Estimated quantities of leather and other nonrubber materials used for shoe uppers are shown in table 2.

Based on tables 1 and 2, it would appear that the number of cattle hides consumed in the side-upper leather market will decline by 20 percent, from 16 million in 1965 to 13 million in 1980. If this trend is not reversed, only about 50 percent of total shoe production will have leather uppers in 1975.

In 1967, calf slaughter produced 6.6 million pieces, the lowest in history. The downward trend in calfskin availability is expected to continue as consumers demand more beef and less veal. Exports of raw skins balance imports, but imports of finished calfskins exceed domestic production. Thus, the long-range supply-demand situation for calfskins appears favorable.

Approximately 12 million sheep and lamb skins are produced from domestic slaughter. Another 25 to 30 million sheep and lamb skins are imported annually.

Table 1.--Estimated domestic cattle hide production and use, 1965-80

Year	Hides produced	Hides used for shoes		Other uses	Export
		Sole leather	Upper leather		
	Million				
1965.....	34	4	16	3	13
1970.....	38	4	16	3	17
1975.....	42	4.5	14.5	3	22
1980.....	46	5.0	13.0	3	27

Source: Estimates based on data from U.S. Bureau of the Census, Tanners' Council of America, and U.S. Department of Agriculture (Agricultural Statistics).

Table 2.--Estimated U.S. market for nonrubber materials for shoe uppers, 1965-75

Year	Total	Leather	Poromerics	Vinyls	Other fabrics
	Million square feet				
1965.....	983	840	5	5	133
1970.....	1,067	786	78	68	135
1975.....	1,182	777	175	90	140

Source: Estimates based on data from Tanners' Council of America.

These skins are manufactured into garment linings and linings for shoes.

Pigskins are used for leather as well as for snacks and gelatin production. In 1967, about 7 million pigskins were used for leather, mostly for side-uppers in shoes. This number is expected to increase to 22 million pieces by 1972.

COMPETITIVE SITUATION

The structure of the industry and the physical characteristics of the basic raw material influence the competitive situation for leather. Leather is sold as a commodity by 80 tanners to 850 shoe manufacturers. Most tanneries are small and their output is not uniform. Most leather substitutes are manufactured and sold by large, market-oriented firms that assure users a uniform product. In addition, firms producing and marketing substitute materials are more research oriented, expend large sums on advertising, and provide technical services to users.

Weight, nonuniform properties, and shape are technical factors affecting the competitive situation for leather. Almost all substitutes weigh about one-third less than leather. This is an important consideration for purchasers of shoes and luggage. It also affects transportation costs in moving the raw material. Most leather is nonuniform in color, thickness, and surface texture. It is much more difficult to maintain uniformity of color in natural materials than in manmade materials. To achieve perfect thickness in leather for adhesive assembly of shoes is also extremely difficult. Biological and physical damage to hides causes nonuniform surface appearance and structure in leather. The irregular shape, imperfections, and small areas

of a hide make it impossible to mechanize or automate cutting of leather. Cutting of substitute materials however, can be automated. Placement of patterns for shoe parts can be predetermined to obtain maximum yield from a given surface area of synthetic materials.

Tannery-run leather sells to shoemakers for 45 to 50 cents a square foot. Most substitutes sell for a lower price. However, the 17 substitutes that are priced at 40 to 90 cents a square foot are considered competitive in price. In comparing leather with its alternatives, users gain certain direct cost savings from using substitutes. Wastes or scraps can be reduced 20 percent and time for cutting can be reduced by 50 percent. These reductions are equivalent to a price differential of 20 cents per square foot between market prices of leather and substitutes.

Consumer attitudes appear favorable toward substitute materials. Market research studies have shown that consumers like the substitute materials primarily because of the easy upkeep due to their nonpolish aspects, color fastness, resistance to wetting, and greater durability. Women's shoes make up about 75 percent of the shoe market. Substitutes at lower prices and lower manufacturing cost can easily gain much of leather's share of this market, since women's shoes are purchased primarily for style and color rather than durability or comfort.

The trend in the hide industry has been to export hides not consumed by the domestic leather industry. To facilitate exports, hides have been listed as a surplus commodity by the Department of Agriculture since 1957. This market cannot expand appreciably because of (1) increasing world availability of hides, (2) growth of substitutes in other countries, and (3) price.

The 850 domestic shoe manufacturers employ 230,000 workers in 38 States. This industry has not expanded with the growing population of the United States. The growth in the U.S. shoe market has been absorbed by imports, chiefly from Italy, Japan, Spain, and the United Kingdom. These imports increased from $118 million or 4.4 percent of domestic consumption in 1965 to $218 million or 7.7 percent of consumption in 1967. Shoe imports not only curtail the growth of the U.S. shoe industry but also reduce the market for U.S. leather. The situation is considered serious, and according to the April 30, 1968, issue of the Wall Street Journal, the President asked the Tariff Commission to investigate how shoe imports are affecting U.S. industry.

COMPETITIVE ADJUSTMENTS

Leather embodies all the variability naturally inherent in hides, plus that introduced by processing. Variations often lead to problems in fabrication on automated machinery. Standards of quality or grade are certainly needed to assure greater uniformity to the shoe manufacturers. In spite of this, two attempts to establish Federal grades and standards for hides and leather were rejected by the industry. The only existing regulation aimed at helping the industry is the Federal Shoe Labeling Act which makes it mandatory to label the type of material used in shoe uppers. The establishment of grades and specifications would provide buyers a more uniform material with known performance characteristics.

Three processes now in the experimental stage may help find alternative markets for hides. One is to tan the hides, grind them into fibers, combine the fibers with a binder, and extrude them in sheet form. Another process is to spin fibers from hide collagen and weave them into a fabric-like sheet. The third process is to convert hide substance into oil and protein for use in cattle feed. All appear feasible, assuming the raw material price is low enough. A price of $2 to $3 per hide is likely to be the maximum, and since hides are worth about $6 for leather material at current prices the new processes may not be economically attractive.

Hide and leather research needs are diverse and extensive. Investigations should proceed along several lines:

(a) The basic properties of hides and leather need to be better understood. Better means to control and modify properties of whole hides during tanning need to be available to processors. More economical processes need to be devised.

(b) New and nonconventional products from hide collagen in the form of films and fibers for use as edible food wraps and binders offer potential high-volume and high-value outlets for hides.

(c) Increased efficiency in hide marketing is possible by removing wasted or low-value parts of a hide as near the supply source as possible. Sorting and standardizing hide output, whether as raw hides or partially processed materials, by the tanning industry can help reduce marketing

costs and improve price-to-quality knowledge for buyers and sellers.

(d) Separation of leather fibers and reconstitution into sheet forms have been accomplished. This technology needs to be considered for various forms, shapes, and compositions heretofore untried.

The supply of hides will increase by about 10 million pieces during the next decade, and declining prices and volumes of use are already evident. Research will be needed if markets are to be retained at current price levels for cattle hides. If these markets can be retained, a gain in gross market value of $114 million will be obtained by 1980.

SUMMARY

Domestic demand for cattle hides has been relatively constant at 22 to 24 million pieces annually since 1958, but it is expected to decline to 21 million pieces by 1980. Currently, there are 69 leather substitutes available, all but 17 of which sell for less than leather. Most of the substitutes have a property superior to leather such as lighter weight, scuff resistance, or dye fastness. Domestic cattle hide availability is expected to increase from 34 million pieces in 1965 to 46 million in 1980 with a hide surplus of 27 million pieces. Because of increased world slaughter and availability of substitute materials at lower prices, exporting large numbers of hides does not appear feasible. Thus, expanding existing markets for leather and finding new and nonconventional outlets for hides, as in food uses, appear to be the most promising means of improving markets for hides.

Synthetic Citrus Drinks

By Clive E. Johnson

The first synthetic citrus drink was introduced to the retail food market in the late 1950's. Other synthetic citrus drinks have been developed since that time and together they have gained a foothold in the citrus fruit and juice market. These synthetic food products were brought into stores in periods when supplies of natural citrus were short and prices high.

NATURE OF SYNTHETIC CITRUS DRINKS

Synthetic citrus drinks are marketed in the form of frozen concentrates or powders. The dry solids used in these products are similar, but the proportions vary among brands and over time. A typical formulation on a dry solid basis consists of approximately 45 percent sucrose, 22.5 percent glucose (dextrose), 22.5 fructose (levulose), 4 to 8 percent citric acid, and 2 to 6 percent other materials, including artificial coloring, vitamins, gums, vegetable oils, sodium carboxymethyl cellulose, orange pulp, sodium citrate, and calcium phosphate. In some synthetic formulations, the fructose may be replaced by additional glucose to improve storage stability.

A powdered synthetic orange drink was made available to consumers in the spring of 1958. This was shortly after the 1957 freeze in Florida and was concurrent with the ensuing short supplies and high prices of natural citrus products. Other flavors of powdered synthetic drinks also have been made available to consumers.

A frozen concentrated synthetic orange drink was market tested in 1963. It achieved national distribution the following year, less than 2 years after the hardest freeze in Florida in the 20th century.

The formulas for synthetic drinks have been modified from time to time to improve quality and provide variety. Similarly, the citrus industry has made progress in developing and improving natural citrus products.

Synthetic fruit drinks have been developed by several companies. However, fragmentary information from a private research agency indicates that sales of most of these products have been meager, markets localized, and product life short.

In addition to the synthetics, a wide variety of natural and frozen concentrated fruit drinks are commercially available. These are fruit juices that have been diluted with varying proportions of water. They contain sugars and sirups, and are usually well fortified with vitamins and minerals. The drinks ordinarily are cheaper than juices, and they may be competitive with natural products. Sales of fruit drinks fluctuate rather widely and their use may decline when prices of natural juices are comparatively low.

Trade associations have suggested that the cost of producing frozen concentrated synthetic drinks is less than half the cost of producing frozen concentrated orange juice. This situation may provide synthetic producers with an advantage in product research, promotion, and marketing.

PRODUCTION TRENDS

Production of oranges in Florida increased from an average of 46 million boxes per year in the 1940's to a record 144 million boxes in 1966-67. The 1966-67 crop represented about three-fourths of the total production of oranges in the United States. A Florida citrus cooperative anticipates that more than 200 million boxes will be produced in the early 1970's, with most of the increase reflecting production from young trees which will have reached bearing age. The record 1966-67 crop had a depressed "on tree" value of about $90 million, whereas in the preceding 9 years annual values ranged from $162 to $256 million.

The market outlet for Florida oranges has shifted rather strongly from fresh use to processed products. About 38 percent of the crop was processed in the 1940's, but 86 percent was processed in 1966-67. About two-thirds of the oranges processed were used for frozen concentrated orange juice. In addition, use of oranges for production of chilled orange juice is increasing rapidly.

Adverse weather conditions, particularly freezes that destroyed trees as well as crops, have kept production of oranges in Florida within manageable levels relative to market outlets in most years. Plantings of oranges in the northeastern part of the State have been virtually destroyed by freezes. Nearly all plantings in recent years have been made in the more frost-free areas of central and southern Florida so that the likelihood of future frost damage is reduced. However, average yields in these areas may be comparatively low because of marginal soils, water problems, and hurricanes.

Production of oranges in California and Arizona decreased from about 48 million boxes per year in the 1940's to 41 million boxes in 1966-67. In contrast to the use pattern in Florida, approximately 82 percent of production in the 1940's and 72 percent of that in 1966-67 was consumed as fresh fruit. The average "on tree" value of oranges in this area in the 1940's was about $108 million compared with $77 million in 1966-67. Increased production of oranges may be anticipated in these States since nonbearing acreage has grown from about 12,000 acres in the 1940's to 73,000 acres in 1965-66.

In addition to the marketing problems arising from expected increases in the size of the orange crop, there is the continued threat of an upturn in production and sales of synthetic orange products. These synthetics have many desirable attributes, such as uniform flavor, good color and texture, and fortification with vitamin C. Some consumers may also find them more convenient to store and easier to use than natural juices.

PURCHASES AND PRICES OF SYNTHETIC AND NATURAL DRINKS AND JUICES

Consumer purchases of natural and synthetic orange juices and drinks on a ready-to-drink basis for 1964-67 are shown in table 1. Purchases of synthetic orange drinks averaged about 48 million gallons in 1965-67 compared with 348 million gallons of natural juices and frozen concentrated drinks.

About 30 percent of families purchased frozen concentrated orange juice each month immediately prior to the 1962 freeze. But, a few months after the freeze, when supplies were short and prices high, the percentage buying dropped to the low 20's. Although sales of natural concentrates are on the upturn, the proportion of families buying concentrated orange juice remains moderately below previous levels (table 2).

Synthetic frozen concentrated and powdered orange products have captured about 5 percent of the household fruit beverage market (table 3). Although sales of the synthetics tend to decline when prices of natural juices are low, they also have risen when promotional efforts were increased. Since production costs of the synthetics are relatively low, promotional expenditures are not as burdensome as they are for natural juices. Advertising expenditures for three of the synthetic products appear to have exceeded the advertising outlay of the Florida citrus industry in 1964 and 1965.[1]

Prices paid by consumers for a 6-ounce serving of natural and synthetic orange juices and drinks during 1964-67 are shown in table 4. In 1965-66, prices of natural frozen concentrated juice were higher than those for frozen concentrated synthetic drinks. In most months of 1967, however, the reverse was true, with the natural concentrate less expensive than the synthetic drinks. On the other hand, chilled and canned orange juices have continued to be more expensive than synthetic products.

[1] Leo Polopolus and W. E. Black. Synthetics and Substitutes and the Florida Citrus Industry. Fla. Citrus Comn. Rpt. FCC-ERD-66-4, Lakeland, April 1966.

Table 1.--Consumer purchases of natural and synthetic orange juices and drinks, ready-to-drink basis, selected periods, 1964-67

Period[1]	Natural juices			Frozen concentrated fruit drinks	Synthetic drinks[2]	
	Frozen concentrated	Chilled	Canned		Frozen concentrated	Powdered
	Million gallons					
1964	175.7	29.1	14.9	25.5	--	--
1965	250.4	35.1	18.3	14.6	22.8	26.8
1966:						
Jan.	25.6	3.8	2.0	.8	1.9	2.4
Feb.	23.0	4.0	2.1	.8	1.7	2.2
Mar.	22.8	4.1	2.3	.7	1.6	2.3
Apr.	20.3	3.7	1.8	.8	1.7	2.1
May	20.2	3.7	1.8	.9	2.1	2.1
June	19.3	3.5	1.6	.9	2.1	2.0
July	18.8	3.3	2.0	.8	1.8	2.0
Aug.	18.9	3.5	2.1	.7	1.4	2.2
Sept.	20.9	3.5	1.7	.5	1.5	2.0
Oct.	21.8	3.5	1.9	.7	1.5	2.0
Nov.	21.3	3.7	1.8	.5	1.5	2.2
Dec.	21.9	3.8	2.0	.5	1.7	2.1
Total	254.8	44.1	23.1	8.6	20.5	25.6
1967:						
Jan.	27.7	3.8	2.7	.5	1.6	2.5
Feb.	28.8	4.3	2.6	.5	1.2	2.3
Mar.	26.6	4.3	2.5	.5	1.4	2.6
Apr.	29.0	4.7	2.1	.3	1.5	2.2
May	25.5	4.6	2.0	[3] .3	1.0	3.0
June	24.5	4.4	2.3	[3] .4	1.0	2.6
July	23.1	4.1	1.8	.4	.9	2.6
Aug.	23.5	4.2	1.9	.5	1.3	2.9
Sept.	25.5	3.9	2.1	.4	1.3	3.1
Oct.	27.3	4.1	2.0	.3	1.5	3.0
Nov.	24.9	4.4	2.0	.3	1.9	2.0
Dec.	26.0	4.5	2.1	.3	1.9	2.4
Total	312.4	51.3	26.1	4.7	16.5	31.2

[1] Data are for 4-week (28-day) periods to facilitate comparisons; years are for 48-week periods.
[2] Synthetic drinks may contain orange pulp or oils.
[3] USDA estimate.

Sources: Florida Citrus Commission and Market Research Corporation of America.

Table 2.--Proportion of families buying natural and synthetic orange juices and drinks, selected periods, 1964-67

Period[1]	Natural juices			Frozen concentrated fruit drinks	Synthetic drinks[2]	
	Frozen concentrated	Chilled	Canned		Frozen concentrated	Powdered
	Percent					
1964 (Apr.)	20.7	6.1	4.2	5.9	--	--
1965 (Apr.)	25.6	6.1	3.9	2.1	3.3	2.7
1966:						
Jan.	27.0	7.8	4.9	1.4	2.6	2.7
Feb.	25.5	8.0	5.1	1.2	2.5	2.8
Mar.	25.6	8.2	5.2	1.1	2.5	2.6
Apr.	24.3	7.4	4.6	1.2	2.4	2.4
May	23.7	7.0	4.5	1.4	3.1	2.3
June	22.9	7.0	4.0	1.5	2.8	2.4
July	22.7	6.9	4.8	1.5	2.3	2.2
Aug.	22.9	6.9	4.6	1.3	2.1	2.6
Sept.	24.2	7.2	4.3	1.3	2.4	2.5
Oct.	25.4	6.8	4.9	.9	2.5	2.3
Nov.	25.0	7.3	4.5	.8	2.1	2.2
Dec.	24.6	7.8	4.8	.6	2.4	2.2
1967:						
Jan.	27.2	7.8	5.5	.6	2.3	2.6
Feb.	28.1	8.6	5.3	.6	1.5	2.5
Mar.	26.6	8.4	5.2	.6	1.9	2.8
Apr.	28.4	8.6	4.5	.5	2.9	3.4
May	25.7	8.5	4.2	.6	2.0	4.7
June	25.3	8.3	4.6	.9	1.7	3.9
July	24.7	7.9	4.0	.7	1.6	4.1
Aug.	24.4	8.1	4.2	.9	1.8	4.1
Sept.	26.3	7.7	4.4	.6	1.8	3.8
Oct.	26.8	7.7	4.7	.5	2.0	3.4
Nov.	25.9	8.0	4.7	.6	2.2	2.9
Dec.	27.5	8.2	4.9	.5	2.3	3.1

[1] Data are for 4-week (28-day) periods to facilitate comparisons.
[2] Synthetic drinks may contain orange pulp and oils.

Sources: Florida Citrus Commission and Market Research Corporation of America.

Table 3.--Share of the retail fruit beverage market held by natural and synthetic orange juices and drinks, selected periods, 1965-67

Period[1]	Natural juices			Frozen concentrated fruit drinks	Synthetic drinks[2]	
	Frozen concentrated	Chilled	Canned		Frozen concentrated	Powdered
	-Percent-					
1965 (Apr.).....	24.3	3.5	2.4	1.7	2.7	3.0
1966:						
Jan.....	27.5	4.7	3.1	1.0	2.4	3.0
Feb.....	25.2	5.0	3.2	1.0	2.1	2.8
Mar.....	24.5	5.0	3.3	.8	2.0	2.8
Apr.....	22.5	4.8	2.8	1.0	2.2	2.7
May.....	21.2	4.4	2.6	1.1	2.5	2.5
June.....	19.3	4.0	2.2	1.0	2.4	2.3
July.....	18.0	3.5	2.6	.9	1.9	2.2
Aug.....	19.5	4.1	2.9	.8	1.6	2.6
Sept.....	23.0	4.3	2.6	.6	1.9	2.6
Oct.....	25.3	4.5	2.9	.9	1.9	2.6
Nov.....	25.0	4.9	2.9	.7	2.0	2.9
Dec.....	25.6	5.0	3.2	.7	2.2	2.8
1967:						
Jan.....	28.1	4.4	3.8	.5	1.9	2.9
Feb.....	28.5	4.8	3.7	.5	1.7	2.9
Mar.....	27.1	5.2	3.6	.6	1.7	3.1
Apr.....	28.6	5.4	2.9	.3	1.7	2.5
May.....	--	--	--	--	--	--
June.....	--	--	--	--	--	--
July.....	22.4	4.7	2.5	.5	1.0	3.0
Aug.....	23.5	5.0	2.7	.6	1.5	3.4
Sept.....	26.8	4.9	3.2	.4	1.6	3.9
Oct.....	28.3	5.0	3.0	.4	1.8	3.7
Nov.....	28.2	5.9	3.2	.4	2.5	2.7
Dec.....	28.6	5.8	3.2	.4	2.4	3.1

[1] Data are for 4-week (28-day) periods to facilitate comparisons.
[2] Synthetic drinks may contain natural orange pulp or oils.

Sources: Calculations by Florida Citrus Commission based on purchases as adjusted by them.

Table 4.--Average prices paid by consumers for a 6-ounce serving of natural and synthetic orange juices and drinks, selected periods, 1964-67

Period[1]	Natural juices			Frozen concentrated fruit drinks	Synthetic drinks[2]	
	Frozen concentrated	Chilled	Canned		Frozen concentrated	Powdered
	Cents					
1964	6.5	8.9	7.4	4.1	--	--
1965	4.7	8.0	5.9	3.6	4.5	4.3
1966:						
Jan	4.2	7.2	5.3	3.5	4.2	4.4
Feb	4.3	7.3	5.1	3.5	4.2	4.3
Mar	4.4	7.5	5.1	3.1	4.3	4.4
Apr	4.5	7.5	5.2	3.0	4.0	4.4
May	4.6	7.7	5.1	3.1	3.6	4.5
June	4.7	7.5	5.2	3.0	3.7	4.5
July	4.8	7.7	5.0	2.8	3.7	4.4
Aug	4.8	7.7	5.0	3.0	3.9	4.4
Sept	4.8	7.7	5.1	3.2	4.1	4.3
Oct	4.8	7.7	5.0	2.3	4.2	4.4
Nov	4.8	7.7	5.2	3.4	4.3	4.4
Dec	4.7	7.2	5.1	3.3	4.2	4.5
Average	4.6	7.5	5.1	3.2	4.0	4.4
1967:						
Jan	4.0	6.9	4.5	3.0	4.2	4.4
Feb	3.6	6.5	4.5	2.9	4.2	4.2
Mar	3.6	6.4	4.4	2.8	4.1	4.4
Apr	3.2	5.9	4.4	2.7	4.1	3.9
May	3.4	5.9	4.4	--	4.1	3.9
June	3.5	5.9	4.3	--	4.1	4.1
July	3.5	6.2	4.4	2.8	4.3	4.2
Aug	3.6	6.4	4.5	2.7	4.2	4.4
Sept	3.6	6.3	4.5	2.9	4.1	4.3
Oct	3.6	6.4	4.6	3.1	3.7	4.2
Nov	3.8	6.5	4.6	3.2	4.6	4.4
Dec	4.0	6.7	4.7	2.9	3.6	4.3
Average	3.6	6.3	4.5	2.9	4.0	4.2

[1] Data are for 4-week (28-day) periods to facilitate comparisons; years are for 48 weeks.
[2] Synthetic drinks may contain orange pulp and oils.

Sources: Florida Citrus Commission and Market Research Corporation of America.

COMPETITIVE ADJUSTMENTS

Production and marketing adjustments are needed to meet the continued threat of synthetic citrus products and to develop new markets for the expected increases in supplies of citrus. Product improvement, cost reductions, improved marketing services, and better management of supply are areas in which further adjustments appear feasible.

A greater variety of improved citrus products could lead to increases in the number of buyers and in the volume of sales needed to move the larger crops anticipated in the future. Research is being devoted to the development and increased use of "essence" to improve the flavor and bouquet of processed products. Several commercial citrus plants are presently recovering "essence" for this purpose. Blends and more highly concentrated juices, along with the more extensive use of synthetic sweeteners, are being market tested. Foam-mat dried orange and other citrus crystals have been developed and are now in commercial production. Orange juice tablets made from these crystals are a more recent innovation but are not yet ready for marketing. Product developments like these are continuing and can be expected to improve the markets for natural citrus products.

The citrus industry must reduce production and marketing costs to compete effectively with synthetic drinks. More efficient mechanical harvesters, pickup machinery, and abscission sprays are being developed as a means of lowering harvesting costs. Packing and processing cost reductions are also being achieved by the design of new equipment, innovations in packaging, and improvements in layout of packing and processing plants. Continued efforts are being made to develop citrus byproducts to increase income and to reduce the problem of waste disposal.

Research to determine the best allocation of fruit between fresh and processed uses should be conducted more extensively. To accomplish this purpose, factors that influence consumer demand for citrus products and competitors in each potential market outlet should be identified and their importance evaluated. Similarly, it may also be possible to make improvements in present methods of distributing fruit and products to markets.

SUMMARY

Since their introduction to the retail trade in the late 1950's, synthetic citrus products in the form of dry powders and frozen drinks have captured about 5 percent of the fruit beverage market. Among the attributes of synthetics are convenience, lower cost, and uniformity of flavor and texture. Efforts by the citrus industry to meet these challenges include the marketing of a wide variety of improved ready-to-drink and frozen concentrated fruit beverages.

Projected increases in citrus output and a continued upturn in production of synthetics are expected to intensify the competitive environment in which citrus products are marketed. Among the innovations now being market tested by the citrus industry are the more extensive use of "essence" to improve the flavor of processed products, blending of juices of higher concentration, and the use of synthetic sweeteners. Continued development of new products, such as orange juice tablets made from foam-mat dried crystals, should further expand the market for natural citrus products and help offset the gains being made by synthetics. Other areas in which the citrus industry may effect improvements are cost reduction, marketing services, and management of supply.

Synthetics and Substitutes for Oilseed Products

By Harry O. Doty, Jr., and John V. Lawler

Oilseeds are generally produced for two basic materials: Oils and meals. These joint products are obtained from several domestic oilseeds--soybeans, cottonseed, flaxseed, safflowerseed, and sunflowerseed. Peanuts and sesameseed are utilized domestically mainly for edible purposes without the oil being extracted. Castor and tung are produced for industrial oil use alone because their oils and meals are toxic.

Synthetic products are now replacing oilseed products in many uses. Most of these uses are industrial, but some synthetics have been approved by the Food and Drug Administration for use in food and feed. Synthetics are expected to continue to make inroads in industrial markets for fats and oils, although the development of some new and improved products may enable fats and oils to gain some new or regain part of some old markets. With the greater emphasis being placed on consumer safety, it is not expected that synthetics will make much headway in the food markets for fats and oils. Oilseed meal probably will continue to be displaced at a high rate in domestic livestock feeds by synthetic urea and fish meal. However, the overall demand for oilseed meal equivalent will hold up well because of the increased demand for protein in overseas markets to feed livestock as well as for use in human diets.

RELATIVE VALUE OF OIL AND MEAL

The relative value of oil and meal has greatly changed since 1947. For example, in 1947 soybean oil accounted for 53 percent of the total soybean crush value, and soybean meal, 47 percent (table 1). Despite the increase in the percentage of oil in soybeans due to improved varieties and more efficient extraction processes, the value of its components changed through the years, and in 1967 the oil made up only 32.2 percent of the total value and the meal 67.8 percent. The change in value relationship of the components of oilseeds was caused primarily by three factors: (1) Increased world supply of fats and oils; (2) large displacement of fats and oils by synthetics in several traditional uses; and (3) increased demand for protein meals to feed livestock.

FATS AND OILS

Fats and oils can be classified in several different ways: (1) according to the origin of raw material used in their production, that is--vegetable, animal, or marine; (2) whether or not they are byproducts such as lard, butter, tallow, grease, cottonseed, and tall oil, or primary products like soybean, linseed, castor, tung, and safflower oils; (3) according to the kind of market in which they are used such as food or industrial, sometimes referred to as edible and inedible product markets, and (4) based on the chemical properties of fats and oils.

Whether a fat or oil is of vegetable, animal, or marine origin is of no consideration for industrial uses and is only of limited consideration for edible use. The domestic food market where origin is important is the kosher trade. However, this factor favors vegetable oils in some food markets since there are no such restrictions against them. Therefore, generally speaking, fats and oils from vegetable, animal, and marine sources usually compete with each other directly, with physical properties, chemical characteristics, and price determining usage. It should be kept in mind that byproduct fats and oils will continue to be produced as long as the processor recovers his cost of processing. Sometimes an integrated company will not recover processing costs but continues to operate.

For many years, roughly two-thirds of the domestic consumption of fats and oils has been for food and one-third for nonfood uses (table 2). The total quantity of fats and oils utilized for food increased from 6.1 to 9.9 billion pounds from 1947 to 1967. During the same period, nonfood use rose from 4.2 to 5.1 billion pounds.

Table 1.--Soybean oil and meal: Yield, price, and value per bushel of soybeans crushed, selected years

Year beginning Sept.	Oil				Meal			
	Yield	Price[1]	Value	Percentage of total value	Yield	Price[1]	Value	Percentage of total value
	Pounds	Cents	Dollars	Percent	Pounds	Cents	Dollars	Percent
1947.....	9.5	23.4	2.22	53.0	47.5	4.15	1.97	47.0
1952.....	10.8	12.0	1.30	43.9	47.3	3.52	1.66	56.1
1947.....	10.8	11.0	1.19	49.0	46.8	2.64	1.24	51.0
1962.....	10.7	8.8	.94	36.0	46.9	3.57	1.67	64.0
1967[2].....	10.6	8.4	.89	32.2	48.0	3.90	1.87	67.8

[1] Simple average price per pound: Soybean oil, crude, tankcars, f.o.b. Decatur, Ill.; soybean meal, bulk, Decatur, Ill., 41% protein prior to July 1950, 44% protein since then.
[2] Preliminary.

Source: Based on data in (15, p. 74). Underscored numbers in parentheses refer to Bibliography, p. 80. Data for 1967 secured from Econ. Res. Serv., Econ. and Statis. Anal. Div.

Table 2.--Fats and oils utilization, selected years

Uses	1947	1952	1957	1962	1967
	Million dollars				
Food uses.....	6,114	6,974	7,624	8,891	9,908
Nonfood uses.....	4,239	3,744	4,085	4,819	5,149
Total.....	10,353	10,718	11,709	13,710	15,057

Source: Based on data in (15, p. 114). Data for 1967 secured from Econ. Res. Serv., Econ. and Statis. Anal. Div.

Not all fats and oils are suitable for food use. Vegetable oils usually are refined before they are suitable. Most food fats and oils can be used industrially, but usually at a lower price. Castor and tung are only used industrially in view of toxic properties. Linseed oil is usually used industrially, although it has been used for food purposes when needed. Inedible tallow and grease are used industrially because they have been declared inedible for esthetic reasons. The distinction between edible and inedible tallow and grease is based on the source of the raw material used in their manufacture. All edible tallow is produced under Federal inspection.

Fats and oils are a unique class of agricultural product in that there is a high degree of interchangeability among them for many products and uses. However, in order for a particular oil to substitute for another oil in a given product, it might be necessary for it to undergo several additional processing steps which may increase its cost before it would be an acceptable substitute. After these additional processing steps, if the oil is readily substitutable in terms of physical and chemical properties in the end-product, then price becomes a major determinant in whether or not the substitution may occur. Small price differences in competing oils can markedly change the proportions of oils used in a product.

In many products, this substitution of some fat or oil for another cannot be 100 percent but oftentimes the formula can

Table 3.--Fats and oils utilization for food, selected years

Year	Butter (fat content)	Lard (direct)	Shortening	Margarine	Cooking, salad oils, and other	Total
	Million pounds					
1947...	1,311	1,817	1,396	607	983	6,114
1952...	1,102	1,826	1,613	1,046	1,381	[1] 6,974
1957...	1,176	1,592	1,824	1,182	1,851	7,624
1962...	1,131	1,320	2,696	1,394	2,534	[1] 8,891
1967...	887	1,057	3,243	1,704	3,017	9,908

[1] Uses do not add to total due to unreported disappearance.

Source: (15, p. 114). Econ. Res. Serv., Econ. and Statis. Anal. Div.

accommodate a somewhat lower rate of substitution. Sometimes blends of several fats and oils are needed to obtain an acceptable substitute for a particular fat or oil. Such is the case now where blends of several domestic oils are being used in place of coconut oil in the manufacture of filled milk.

Shifts in usage of the various fats and oils are taking place all the time. For example, there has been a major shift in fats and oils used in shortening. In 1935-39, soybean oil accounted for 8 percent and cottonseed 66 percent of the total fats and oils used in shortenings. In 1967, the proportion had changed so that soybean oil accounted for 54 percent and cottonseed only 8 percent of the total.[1] Some oil products are more subject to the interchange of fats and oils than others. Shortenings and margarine are two oil products having a high degree of interchangeability of fats and oils used in their manufacture. Also, some manufacturers make these shifts among oils more readily than others. This in part may be due to a manufacturer's fats and oils raw materials position as well as other factors.

Food Fats and Oils

In addition to the interchangeability of fats and oils in the manufacture of a given product, there is also the substitution of one fats and oils product for another. A shift from animal fats to vegetable fats has taken place in food uses (table 3); margarine replaced butter as a table spread to a considerable extent and vegetable shortening captured much of lard's market as a cooking fat. Now underway is a shift from solid fats to liquid oils. These shifts in demand for fats and oils products will continue to take place as manufacturing processes are developed or improved, economics of production of raw materials shift, and tastes and eating habits of the population change. However, domestic consumption of food fats per person is expected to stay at about the same level in the foreseeable future.

There are relatively few areas where synthetics substitute for food fats and oil. Therefore, at the present time, most of the substitution of synthetics for fats and oils takes place in industrial uses.

Food Surfactants

There is one area in which synthetics have been used in the past and stand as a major threat in the future to fats and oils markets in food. This is the area of food surfactants (short for surface-active agents)--often referred to as emulsifiers or bread softeners.

Monoglyceride emulsifiers (derived from fat) have been strongly entrenched in the shortening outlet. In the last decade, however, several different types of partially synthetic emulsifiers have been approved by the FDA for use in bakery and related products. Partially synthetic emulsifier types are the lactoglycerides, sorbitol esters, lactic acid derivatives, and propylene glycol esters. Examples of each of these types are glycerol lactopalmitate, polyoxyethylene sorbitan monostearate, stearyl-2 lactylic acid, and propylene glycol

[1] Based on data in (12, p. 24).

monostearate. These emulsifiers usually are composed of a lipophilic or oil soluble portion that is fat derived (stearic, oleic, palmitic, and other fatty acids).

Food surfactants are commonly used to enable oil and water phases to mix and form an emulsion. In addition, surfactants perform many other functions in foods: They retard hardening, reduce stickiness, retard loss of gloss or bloom, improve opacity in sugar coatings, reduce pastiness, improve palatability, increase the physical volume of ice cream during manufacture, disperse flavor components, prevent seepage of oil, and control crystallization. This diversity of benefits creates markets for many different surfactants, each with its own unique advantages and disadvantages. The technology of blending food surfactants has greatly helped the development of the ever increasing variety of prepared food products.

Food products in which emulsifiers are widely used are shortening, margarine, peanut butter, frozen desserts, candy, salad dressings, baked goods, frozen eggs, and pasta products (5).[2] Before the introduction of synthetic surfactants, naturally derived materials such as lecithin, saponins, and lipoproteins were used in the food industry.

Although thousands of synthetic and natural substances can be classified as surfactants, only a few are approved for food use by the Food and Drug Administration. The FDA not only approves the surfactants that can be used in foods but also sets levels for their safe use.

The present estimated market for additive emulsifiers is about 74 million pounds (table 4) (21). Others have estimated this market and arrived at different figures (29). About two-thirds of these additive food emulsifiers are monoglycerides, which are wholly fat-derived products with emulsifier characteristics. The other one-third (26 million pounds) consists of several different emulsifiers, most of which are part synthetic and part fat-derived materials.

In addition to additive emulsifiers, there is the larger amount of monoglyceride emulsifiers which occur naturally or are formed in situ by glycerolysis in shortening. This production of monoglycerides in shortenings is estimated to be about 150 million pounds.[3]

In the application of emulsifiers in fats and oils products two types of substitution may take place: (1) synthetic emulsifiers substituting for fat derived emulsifiers and (2) use of synthetic emulsifiers to displace fats and oils or to reduce the amount of fats and oils currently used in food products. Of course, the latter type of substitution is the greatest threat to the present use of fats and oils in food products.

Table 4.--Estimated use of food emulsifiers, 1967, and expected increase, 1972[1]

End-use	1967 estimate	1972 market increase expected from normal growth
	- - -Million pounds- - -	
Bakery goods.....	48	8
Prepared mixes.....	10	2
Confectionery.....	9	1
Frozen desserts....	5	1
Convenience and instant foods....	2	1
Total.....	74	13

[1] Includes only emulsifiers added as separate ingredients (i.e., excludes shortening emulsifiers that occur naturally or are formed in situ by glycerolysis).

Source: Estimates based on data in (21, p. 10).

The use of emulsifiers in bread and other products often allows the manufacturer to reduce the total amount of fat he uses. However, in bread he still must use some fat in order for the dough to be machinable. In manufacturing cakes, the use of emulsifiers allows him to cut down not only the amount of fat but also the amount of eggs. Emulsifiers also allow him to increase the ratio of sugar to fat, thus increasing the sweetness and lightness of the cake.

Prior to World War II fat accounted for about 4 percent of the ingredients in bread. Since then, widespread use of emulsifiers has taken place. In 1950, about 3 percent fat was used in bread, and now fat usage in bread is about 2 percent. The decrease in fat level in bread is mostly due to the use of monoglyceride emulsifiers.

It is estimated that the baking industry utilizes about one-fifth of all food fats and oils used in this country (8), or approximately 2 billion pounds. This market is the most susceptible to inroads of synthetic

[2] Underscored numbers in parentheses refer to Bibliography. p. 80.

[3] Updated from data in (21, p. 6).

emulsifiers, and their impact is already being felt. Some sources indicate that these emulsifiers reduce the amount of shortening needed up to 20 percent (21).

The use of partially synthetic emulsifiers is not limited to commercial bakery products. Overall application might result in replacement of fats and oils in home baking, in the cereal mix industry, in prepared baking mixes, in salad dressings, and in other food uses.

Industrial Fats and Oils

Since World War II, major changes have occurred in the industrial markets for fats and oils. There has been an increasing use of plastics and synthetic resins and a decline in use of drying oils. Use of synthetic detergents has increased with a consequent decline in the volume of fats and oils used in soapmaking. Two major new markets have developed for fats and oils, in animal feeds and in the manufacture of fatty acids. Both of these markets are included in "other industrial uses" (table 5), which increased 400 percent between 1947 and 1967.

Drying Oil Uses

Since World War II, vegetable oil use in drying oil applications has declined at an average rate of 1.7 percent annually--from an annual average of 957 million pounds for 1946-50 (15) to 686 million pounds in 1967. Since 1950, a decline in drying oil use has occurred each year from the previous year in 10 out of the 17 years 1950-67. The maximum postwar drying oil usage was 1,075 million pounds in 1950 and the smallest was 678 million pounds in 1966. This decline is expected to continue. There are few new uses for drying oils and present uses are holding steady or declining, because of increasing use of plastics and synthetic resins which have a more salable performance or lower price or both. A reversal or even lessening of this downward trend of drying oil usage is unlikely.

In the last decades, linseed oil and soybean oil have comprised about three-fourths of the total drying oil usage. Relatively high price and uncertain supply have discouraged industrial consumers from specifying the smaller volume vegetable oils (safflower, tung, oiticica, dehydrated castor, etc.) in their large-volume formulations. Only linseed oil and soybean oil have been available in relatively large and predictable volume. In recent years, soybean prices usually have been 2 to 3 cents per pound less than linseed, so soybean oil usually has been used unless performance requirements cause linseed or another vegetable oil to be used. It is believed that linseed and soybean will continue to dominate the drying oil market.

A promising new use for linseed oil developed through research is as a curing compound and antispalling agent in highway construction. Several State highway departments are currently evaluating this use of linseed oil. Tallow is also being evaluated for this use.

The declining use of vegetable oils in drying oil applications has been caused not only by the development of synthetic resins but also by the availability of two lower priced drying oils not of an oilseed origin--tall oil and fish oils. Both oils have been available at 1 to 3 cents per pound less than

Table 5.--Fats and oils in nonfood uses, selected years

Year	Soap[1]	Drying oil		Other industrial uses	Total
		From oilseeds	Total[2]		
	Million pounds				
1947.....	2,331	938	1,017	891	4,239
1952.....	1,416	910	1,032	1,296	3,744
1957.....	1,037	871	1,032	2,017	4,085
1962.....	796	702	876	3,147	4,819
1967.....	714	686	855	3,580	5,149

[1] Excludes an estimate of oil equivalent of soap used in synthetic rubber. This is included in the "other industrial uses" category.

[2] Includes oil from oilseeds, tall oil, and fish oil.

Source: (15, p. 114). Data for 1967 and for drying oil from oilseeds secured from Econ. Res. Serv., Econ. and Statis. Anal. Div.

soybean oil. Also, tall oil is finding increasing use because improved refining techniques have made possible a product with less than 2 percent rosin.

Soybeans are grown in the United States over a wider area and in larger quantities than any other oilseed. They are grown in about all agricultural States with a moderate climate east of the Rockies. In contrast, tung, castor, safflower, and flaxseed can be grown in only rather limited regions. Hence, of the oilseeds, only soybeans have the advantage of local availability in meeting foreseeable future oilseed demands by the edible and industrial domestic markets and export markets.

Paint.--The paint (surface coatings) industry consumes about 90 percent of the oils going into drying oil products. Hence, the future use of vegetable oils in drying oil markets largely depends upon the use of linseed and soybean oil in surface coatings. Surface coatings had a 5.5 percent average annual growth rate from 1961 to 1966, increasing from an annual average of 643 million gallons in 1960-62 to 837 million gallons in 1966 (24). Generally, the demand for surface coatings is related to overall economic growth--new housing starts and production of automobiles and appliances. Trade sales paint in this same 5-year period had a 4.3-percent average annual growth rate and industrial coatings had a 6.6-percent average annual growth rate.

Vegetable oil use in trade sales paint is declining because of the growing popularity of water-emulsion latex paint. Latex paint constituted about 64 percent of interior coatings and 29 percent of exterior coatings in 1966. In 1964, these percentages were 59 and 19, respectively. Water emulsion paints are expected to continue this growth not only because consumers like the ease of application and cleanup, but also because these paints do not contain volatile solvents which are a fire hazard. Furthermore, three of the top six paint companies are producers of one or more of the synthetic resin monomers used in latex paint; e.g., vinyl acetate and acrylonitrile. Most paint companies have no raw materials position and tend to produce those paint systems which are both more profitable to the company and more popular with the public. The threat offered by latex paints to alkyd resin and oil-based coatings does not appear to be as great as it was a few years ago. Many latex paints sold for exterior use now contain or recommend the use of a primer coating (usually a drying oil base) to promote more rapid wetting and/or adhesion.

The increasing concern for air pollution is a small but important factor in the increasing use of water systems for paints. Also, in a few years, use of eletrocoating or some other water system in automotive and appliance production is expected to be more widespread.

Printing ink.--While the quantity of vegetable oils in printing inks is much smaller than the quantity used in paints, the printing ink industry is experiencing a trend similar to the paint industry. Because of the demand for faster printing speeds, synthetic resins which dry faster than the vegetable oils are being used in increasing amounts.

Calking compounds.--Calking or sealant compounds, especially the putty type used traditionally to seal house windows, contain linseed oil. However, extensive use of glass, especially in commercial buildings, has caused a shift to various synthetic elastomers and plastics: Neoprene, vinyl, polybutene, polysulfide, etc. These man-made products are used widely despite their relatively high price ($0.50-$2 per pound) because they retain their elasticity for a long time. A drying oil putty becomes hard and dry with age. The expense of replacing the calking or sealing material is several times the saving in using a putty containing a drying oil rather than a more expensive elastomeric sealant. Putty will continue to be used in a significant but declining share of windows in new housing and replaced windows in older housing. The tendency toward prefab housing is resulting in increasing use of elastomeric or vinyl sealant or channeling material.

Floor covering.--Before World War II, about 80 to 100 million pounds of linseed oil were used annually to make linoleum. The development of vinyl floor tile has caused this use of linseed oil to decline to about one-tenth of the prewar amount. The preference for the vinyl floor coverings should all but make this linseed oil market disappear. Furthermore, more tall oil than linseed oil is now used in this declining linoleum market.

Oilcloth.--Until the late 1940's, oilcloth was the principal material used for covering kitchen tables. About that time polyvinyl chloride film began to be used for this purpose and gradually increased its share of the market until today almost all kitchen table covering is polyvinyl chloride or polyethylene. Oilcloth has all but disappeared. There have been reasons for this raw material change: Superior performance and lower price for the petrochemical product. The plastic films have equal drape and wipe as easily as oilcloth.

Soap and Synthetic Detergents

Historically, soap has been one of the biggest markets for fats and oils, using as much as 2.3 billion pounds in 1947 (table 5). The last 25 years have seen a dramatic decline of this once important market, because synthetic detergents primarily of petroleum origin now account for a major share of this market (82 percent in 1967).

Use of synthetic detergents has increased because their performance has some advantages over that of soap. Unlike soap, synthetic detergents do not form insoluble compounds when used with hard water. The formation of these insoluble products is one of the biggest disadvantages of using soap. These insoluble precipitates of calcium and magnesium soaps result in the dulling of fabric colors and in the familiar bathtub "ring." Synthetic detergents also possess a stronger defatting effect.

Synthetic detergents had a very rapid growth in the 1940's and 1950's but have had a slower growth rate in recent years. In the last 5 years the average annual growth rate has been about 3.3 percent, increasing from 4,420 million pounds in 1962 to 5,200 million pounds in 1967 (table 6). It is believed this growth rate will gradually decline because synthetic detergents have probably reached the limit of their share of the soap and detergent market unless they become more successful in penetrating the toilet bar market.

Sales of soap and synthetic detergents combined grew at an average annual rate of 2.4 percent from 3.92 billion pounds in 1947 to a record high of 6.31 billion pounds in 1967 (table 6). This increased soap and synthetic detergent use is due not only to average population increase (about $1\frac{1}{2}$ percent annually) but also to increasing per capita use (about 0.8 percent annually). The average person used about 24 pounds annually in the late 1930's, about 26 pounds in the 1940's, and about 30 pounds in the 1960's (15). This per capita increase presumably is due to the gradual increase in the standard of living in the United States since the 1930's. Thus, the total soap and synthetic detergent market has had a modest growth independent of population growth.

It is believed that the current use of soap and synthetic detergents may level off. Increasing American affluence tends to result in greater use of paper substitutes for bedsheets, dresses, napkins, etc. Disposable paper items may be preferred by hospitals and other institutions for both sanitation and cost reasons. Also, times of significant military activity tend to cause an increase in soap and synthetic detergent consumption which is only temporary.

Soap sales reached their peak, 4,090 million pounds in 1944 (table 6). Since then, a decline has occurred for 20 of the last 23 years, averaging 5.5 percent annually. The big displacement of soap by synthetic detergents occurred in the late 1940's and in

Table 6.--Soap and synthetic detergents, domestic sales, and per capita disappearance, selected years

Year	Estimated sales[1]			Civilian per capita disappearance		
	Soap[2]	Synthetic detergents[3]	Total[4]	Soap	Synthetic detergents	Total
	Million pounds	Million pounds	Million pounds	Pounds	Pounds	Pounds
1944...	4,090	125	4,215	29	1	30
1947...	3,512	408	3,920	24	3	27
1952...	2,210	1,856	4,066	14	12	26
1957...	1,430	3,500	4,930	8	20	29
1962...	1,210	4,420	5,630	7	24	30
1967[5]..	1,110	5,200	6,310	6	26	32

[1] Estimates of Soap and Detergent Association. Data are on the built, finished weight basis. [2] Excludes scouring cleansers and liquid soaps. [3] Includes only those solids and liquids with end-uses and characteristics similar to soap. Excludes scouring powders and shampoos where possible. [4] Total includes exports which have ranged from 1 to 4 million pounds annually. [5] Preliminary.

Source: (15, p. 146). Data for 1967 secured from Soap and Detergent Association.

the 1950's. In 1962-67, however, the average annual rate of decline for soap sales was about 1.7 percent.

About 90 percent of the soap being used today is toilet bar or hand bar soap. Most of the remaining soap is used by commercial laundries. Soap is expected to continue to dominate the bar soap market because the synthetic detergent bar is more expensive and has inferior properties. As a synthetic detergent bar becomes small, it has a tendency to crumble or dissolve much more than a soap bar. Another disadvantage of synthetic detergent bars is that they do not have the same effect on the skin as fat-derived bar soap. They dissolve more oil out of the users' skin than soap, thus they leave the hands feeling dirty. To overcome this disadvantage, synthetic detergent bar manufacturers add cold cream or other emollients to provide this mechanical effect.

Many commercial laundries, especially in hard water areas, find that soap plus soft water is cheaper than synthetic detergents because they have already depreciated water-softening equipment (32).

There is no known way of making any of the present raw materials for synthetic detergents at a lower cost from fats and oils than from petroleum sources. The uncertain price of tallow, in contrast to the greater predictability of n-paraffin prices, is an additional reason for more biodegradable synthetic detergents of the future to be manufactured from petroleum sources rather than animal or vegetable fats and oils.

Fats in Feeds

The largest new domestic market which has been developed since World War II for industrial fats and oils is in animal feeds. Fats and oils are widely used in prepared animal feeds by all sizes of feed mills throughout the United States (7). Use of fats in feeds began in a major way in 1953 and has shown rapid expansion (table 7). The average annual growth rate of inedible tallow and grease used in feeds for the past 10 years is 8.7 percent. In addition to reported usage, an estimated 50 to 60 million pounds of other fatty materials are used in feeds. Also, oilseed mills and alfalfa mills add fatty materials, for which there are no quantity estimates, to the meals they produce.

It is anticipated that the quantity of fats added to feeds will continue to grow. This growth is based on several trends: (1) increased production of commercial feeds, (2) higher proportion of feeds being pelleted,

Table 7.--Fat use in feeds, selected years

Year	Inedible tallow and grease	Total fat use
	Million pounds	
1954.....	111	132
1957.....	425	462
1962.....	822	872
1967.....	972	NA

Source: (15, p. 105). Data for 1967 and total fat use secured from Econ. Res. Serv., Econ. and Statis. Anal. Div.

(3) increased bulk handling of feeds, (4) more widespread application of fats to feeds, and (5) an increase in the level of fat added (6).

Fats are added to various types of feeds at different levels from one-half to 10 percent. When fat is used at levels above 2 percent, it is primarily for its energy value. Highest levels of use are found in poultry feeds. Fat use in broiler feeds at the 4 percent level is a common practice (6).

Fats are added to feeds for several reasons: (1) for caloric or energy value, (2) as a growth factor, (3) to increase feed efficiency, (4) to increase palatability, (5) to reduce dustiness, (6) to make for easier handling, (7) to reduce wear (lubricant) on handling, mixing, pelleting, and other machinery, (8) to aid in homogenizing and stabilizing the mixture of fine particled feed additives, and (9) to give feed a better appearance (6).

The threat to the market for fats in feeds comes from the petroleum industry. There is a possibility of mineral oil being used in place of fat in feed formulations. However, mineral oil could not perform all of the functions of fat enumerated above. Mineral oil would probably perform functions 5 through 9 listed above satisfactorily. One-half to 1 percent fat is usually added to many feeds to perform these functions. Therefore, mineral oil could possibly capture about one-third of the current fat usage in feed markets.

The Food and Drug Administration currently allows the use of mineral oil, meeting certain specifications, in feeds up to 0.6 percent of the ration. It also allows up to 3 percent mineral oil in mineral supplements. Relatively little mineral oil is being used in feeds and feed ingredients because of its

lack of food value and the current low prices of tallow and grease compared with mineral oil. At the present time, mineral oil, white, technical grade, is selling for 59 cents per gallon while the grades of tallow and grease used in feed are currently selling between 4 and 5 cents per pound (31 to 39 cents per gallon). However, some mineral oil is being used as a carrier of an antioxidant and applied to alfalfa meal. With the outlook for ample supplies of tallow and grease being available in the future, it appears that little or no additional mineral oil will replace fats and oils in feeds in the foreseeable future.

Fat Derivatives

Fatty Acids

Fatty acids are of two general types, saturated and unsaturated. The saturated acids, solid at room temperature, are usually stearic and palmitic (principally from tallow) while the unsaturated acids, liquid at room temperature, are usually oleic and linoleic (the latter principally from tall oil).

Stearic and palmitic acids are used to make soap, detergents, cosmetics, candles, waxes, and chemical intermediates. The rubber industry uses about 40 million pounds of stearic acid annually, half for compounding and the other half in the emulsion copolymerization of styrene and butadiene to make the SBR type of synthetic rubber.

The unsaturated acids are used in paints, printing inks, metallic driers, soaps, detergents, flotation agents, cutting oils, lubricating oils, linoleum, and chemical intermediates.

Use of fatty acids grew at an average annual rate of 7 percent, from an average of 776 million pounds in 1961-63 to 1,089 million pounds in 1967 (table 8). In dollar value, this would be about $100 million. A peak production of 1,134 million pounds occurred in 1966. About 90 to 95 percent of the amount produced is used domestically. Exports account for 5 to 10 percent.

Inedible tallow and grease and tall oil are the principal raw materials for fatty acids--providing about 90 percent of the fatty acids produced during each of the 3 years, 1965-67. Most of the remainder is produced from vegetable oil foots or soapstock, a byproduct of the refining of vegetable oils.

Tall oil consists of approximately equal parts of rosin acids and fatty acids. Approximately 90 percent of tall oil production is fractionated to produce these acids. Tall oil from its initial use in the early 1940's has been an increasingly important source of unsaturated fatty acids (oleic and linoleic). In 1967, tall oil accounted for an estimated 62 percent of the total fatty acid raw materials, but less than 40 percent of the fatty acids produced (30).

Tall oil used for fatty acid production increased from 725 million pounds (annual average for 1961-63) to 1,167 million pounds in 1967--an average annual growth rate of 10 percent. If prices of crude tall oil per pound continue to be lower than other sources of fatty acids (inedible tallow, soybean oil,

Table 8.--Fatty acid production and fats and oils used in manufacture, selected years

Year	Fatty acid production (all grades)	Fats and oils used in producing fatty acids			
		Inedible tallow and grease	Tall oil	Other[1]	Total
	Million pounds				
1947.....	474	193	(2)	187	380
1952.....	548	187	(2)	225	412
1957.....	505	284	264	189	737
1962.....	785	411	720	188	1,319
1967[3].....	1,089	545	1,167	180	1,892

[1] Includes coconut oil and vegetable foots.
[2] Not reported to avoid disclosure.
[3] Preliminary.

Source: (9, p. 33).

etc.), as they have been in the 1960's, then crude tall oil should continue to be a major source of fatty acids.[4] In addition to its low price, tall oil has a large and dependable supply.

Inedible tallow in the 1960's has averaged about 30 percent of total fatty acid raw materials. This should continue as long as inedible tallow price remains low; furthermore, tallow is the only commercial source of stearic acid. Inedible tallow use for fatty acid production increased from 405 million pounds (annual average for 1961-63) to 545 million pounds in 1967--an annual growth rate of 6.1 percent. A high of 583 million pounds was used in 1966 (25).

Thirty years ago, soapmaking used about 80 percent of the inedible tallow and grease and the fatty acid market took a relatively small amount. The market picture for domestically used inedible tallow in recent years has changed considerably. The amount of inedible tallow used recently in soap manufacture has ranged from 25 to 30 percent and fatty acid used about 20 to 25 percent. There are two other large markets for inedible tallow which did not exist 30 years ago. Exports now take about half the amount produced and animal feed use takes about 35 percent to 40 percent of inedible tallow used domestically. Lubricants and miscellaneous uses account for the remaining consumption (11).

Petroleum as a low-cost source of fatty acids continues to be a potential threat to tallow and other fats and oils. Synthetic fatty acids can be produced by several different processes. While there is considerable research on synthetic fatty acids being conducted by the petrochemical industry, there is only small-scale production currently in this country. This production has been limited to special high-priced fatty acids.[5] The low prices of tallow and tall oil have, so far, suppressed any synthetic commercial production of the conventional fatty acids. At the present time, short chain fatty acids (C_8-C_{14}) produced from higher priced coconut oil are more vulnerable to substitution by synthetic fatty acids. Synthetic fatty acids are reportedly being commercially produced from petroleum in Russia and satellite countries where there is a shortage of tallow and coconut oil for soap (35). Up to now, the quality of this output has been described as having undesirable odor, taste, and poor color stability. However, it is believed that improved purification techniques in the future will make the properties of these synthetic fatty acids equal to natural products.

The commercial feasibility of synthetic fatty acids depends not only upon the development of technical processes but also upon the future price level of the natural raw materials--inedible tallow and tall oil--and the price of the fatty acids made from these raw materials. Both tallow and tall oil are byproducts. As long as pork and beef are consumed in this country, tallow will be available in large quantities with no regard for tallow demand. As indicated above, about half of the available tallow in this country is exported. If the export market should decline, this large quantity of tallow will probably exert economic pressure to lower the price of tallow. With the increasing expansion of the paper industry and especially the sulfate process, increasing amounts of tall oil are available to the chemical industry at byproduct economics. Increasing concern about stream pollution is another factor to cause the paper industry to upgrade as much as possible what were formerly waste products and to sell the byproduct at a price high enough to recover processing costs.

Other Fat Derivatives

Fatty alcohols were made from tallow, coconut oil, and sperm oil before 1963, but since then, four large commercial facilities (each varying from about 18 to 45 million pounds in yearly capacity) have been built by petrochemical companies to produce synthetic fatty alcohols. Data from the Tariff Commission indicate that the production of C_{10} and higher alcohols was 369 million pounds in 1965 and 469 million pounds in 1966. Based on information from the Chemicals Division of the Tariff Commission and from industry contacts, it is believed that 50 to 70 percent of the raw materials for fatty alcohol production are

[4] Low and high average annual prices per pound of selected fats and oils, in tank car quantities, 1960-68 (Jan. - Aug.):

	Low	High
	---- Cents ----	
Tall oil, crude, works	2.8	3.6
Tallow, No. 1, inedible, Chicago	4.2	7.2
Soybean oil, crude, Decatur	8.4	11.7
Coconut oil, crude, New York	11.8	18.7

Source: (15). Data since 1965 obtained from Econ. Res. Serv., Econ. and Statis. Anal. Div.

[5] These acids include 2-ethylhexanoic, pelargonic, isostearic, phenylstearic, and the trialkylacetic acids as reported in (27).

petrochemicals and the remaining 40 to 50 percent are of natural origin--tallow and coconut oil. The major end-use of fatty alcohols is in surface-active agents which are active ingredients in household detergents, toothpastes, and shampoos.

Fatty nitrogen derivatives (principally fatty amines, amides, and quaternary ammonium salts) are another area in which petrochemical feedstocks are threatening animal and vegetable raw materials. Industry contacts estimate that 70 to 75 percent of the fatty amines are currently made from tallow, 20 to 25 percent from coconut oil, and about 5 percent from petrochemical sources.

Tariff Commission data indicate that about 250 million pounds of fatty nitrogen derivatives were produced in 1966 and about 230 million pounds in 1965. No information is available on the amount of the various raw materials used to make these fatty nitrogen products. Most of the fatty nitrogen products find use as surface-active agents: Household detergents, ore flotation chemicals, textile wetting and softening agents, etc.

It is believed that the petrochemical process will offer more competition in the immediate future to the derivatives made from coconut oil than to the derivatives made from tallow as long as the price of coconut remains relatively high (about 15 to 20 cents per pound) and the price of tallow remains relatively low (4 to 7 cents per pound).

Glycerine

Glycerine is a versatile raw material having uses in both edible and inedible product markets. Historically, natural glycerine has been a byproduct of soap, fatty acid, and fatty alcohol manufacture and the supply naturally depended on the demand for these products--not on the demand for glycerine. In contrast, most glycerine from synthetic sources is the main product and producing companies adjust their percentage of capacity operation to anticipated business conditions. Since 1948, synthetic glycerine has been commercially available from petrochemical sources and has become increasingly important, now accounting for about 60 percent of the total supply. This increasing availability of glycerine from petroleum sources has tended to minimize both price rises and periods of short supply.

Domestic production of glycerine (synthetic plus natural) had a 3.0 percent average annual growth rate during a 17-year period, from 226 million pounds in 1950 to 370 million pounds in 1967 (26, 34). In the 5 years from 1961 to 1966, glycerine from natural sources increased at an average annual rate of 2.3 percent, from 138 million pounds in 1961 to 155 million pounds in 1966, while glycerine from petroleum sources increased at an average annual rate of 7.3 percent, from 141 million pounds in 1961 to 200 million pounds in 1966. Thus, it is expected that almost all the future growth of glycerine will be from petroleum sources. Estimates of future annual growth for total glycerine (synthetic plus natural) vary from 3 percent (a continuation of past production trend) to 4.5 percent (1).

Currently, there are four major producers of glycerine from natural sources. About two-thirds of the glycerine from natural sources is from soap manufacture. This proportion should increase if petroleum becomes the raw material for production of fatty acids and fatty alcohols. There is no glycerine byproduct when this source is used.

There are three producers of synthetic glycerine.[6] A fourth company reportedly planned to begin production in December 1968.

Glycerine is used for its chemical properties as well as its physical properties. The biggest single use is to make alkyd resins which in turn are widely used in decorative and protective coatings where toughness, durability, and color retention are required (table 9). The use of glycerine in alkyd resins should remain constant or decline as latex coatings gradually replace alkyd solvent coatings.

The second largest use of glycerine is in drugs and toilet goods and is one of the fastest growing uses. About 60 million pounds of glycerine were used in 1966 to make drugs, cosmetics, toothpaste, and mouthwashes, compared to 35 million pounds in 1961.

Tobacco products (especially cigarettes) use glycerine as a humectant. This use will, therefore, follow trends in tobacco consumption which may have a growth rate of 1 to $1\frac{1}{2}$ percent annually. Glycerine acts as a plasticizer in cellophane, which represented in 1966 a market of 45 million pounds for glycerine. Strong competition to cellophane in the future from polyethylene, polypropylene, and polyvinyl chloride films

[6] One of the processes used is actually semisynthetic since it involves the hydrogenation of carbohydrates which make various polyols. Sorbitol is the primary product, glycerine is a lesser product (2, p. 52).

Table 9.--Estimated consumption of glycerine, by end-product groups, 1962 and 1966

End-product	1962	1966
	-Million pounds-	
Alkyd	70	70
Tobacco	35	43
Cellophane	50	45
Explosives	15	23
Drugs and toilet goods	35	60
Foods and monoglycerides	15	30
Urethane foams	--	14
Triacetin (plasticizer)	--	4
Miscellaneous	37	36
Total	257	325

Source: (10, p. 27).

is expected to cause this use of glycerine to decline. The trend toward prepared foods should cause an increase in the amount of glycerine (30 million pounds in 1966) used in food and beverages as an emulsifier, humectant, solvent, sweetener, and preservative. Edible monoglycerides are included in formulations for margarine, shortenings, salad dressings, frozen desserts, coatings for candy and food, etc. The use (23 million pounds in 1966) in explosives should be in proportion to military activity, although changing technology in the explosives industry has already led to a preference for ammonium nitrate-fuel oil mixtures over nitroglycerine for some types of military and nonmilitary explosives.

Prior to the middle 1950's, the price of glycerine was quite sensitive to market demands. The supply could not be expanded or contracted very much, because glycerine is a byproduct and the demand for soap, the principal product, is somewhat inelastic whether business conditions are good or bad. Since the middle 1950's, the price of U.S.P. natural glycerine has apparently followed closely the price of synthetic glycerine. In the 14 years from 1954 to 1967, the price of 99.5 percent synthetic glycerine varied from a high of 30.7 cents per pound in 1954 to a low of 19 cents per pound in 1963 (26). Since 1963, the price has gradually increased to 24.75 cents per pound in 1968. Planned expansion of synthetic glycerine production, and the continued availability of natural glycerine, should lessen the pressure for further price increases in the immediate future.

OILSEED MEALS

The production of oilseed meals in the United States increased from 10.6 million tons in 1956-57 to 15.6 million tons in 1966-67 (table 10). The annual rate of growth was 4.0 percent. In the past 20 years, there has been a 250 percent increase--nearly all from the increased production of soybean meal.

Although cottonseed meal production increased considerably from the 1947-57 level (see table 10) it recently experienced a rapid decline. In 1966-67, production was about one-third less than a year earlier, due to the cotton diversion program and adverse weather conditions. Cottonseed meal production is now at about the same level it was 20 years ago. Cottonseed and the oil and meal derived from it are byproducts of the cotton industry. Therefore, cottonseed production (and the oil and meal from it) does not have the growth potential of soybeans whose oil and meal are directly responsible for its production. Production of other oilseed meals has also declined, primarily because of the lower flaxseed production.

Soybean meal now accounts for over 85 percent of the high-protein oilseed meal produced in the United States and over 96 percent of our exports of oilseed meals. Soybean meal production had an average annual growth rate of 5.4 percent from 1961-62 to 1966-67 and 6.0 percent from 1956-57 to 1966-67. In 1966-67, feed use took about 80 percent, exports about 20 percent, and other uses (mainly the adhesive field) less than 1 percent of our soybean meal disappearance.

Exports of soybean meal in 1966-67 were over 2 1/2 times what they were in 1961-62 and 6 times what they were in 1956-67 (table 10). Export markets are expected to continue strong in the next few years with rising livestock numbers abroad, increased knowledge of feeding value of soybeans, and increased demands for edible protein. However, traditional export markets always have favored the purchasing of whole soybeans. Then, the importing country can build its own extracting facilities, employ its own capital and labor, and have both the oil and meal for its own use. Western Europe is increasing its crushing capacity, which will have a direct impact in the future on our shipments of soybean meal to this part of the world. Urea substituting for soybean meal in animal rations is not as great a threat to overseas markets as it is to domestic markets at the present time because

Table 10.--Production and disappearance of oilseed meal, selected years

Year (beginning October) and type of meal	Production	Disappearance		
		Domestic[1]	Exports	Total
	1,000 tons			
1946-47:				
Soybean.....	4,087	3,745	142	3,887
Cottonseed.....	1,428	1,434	5	1,439
Other.....	690	658	31	689
Total.....	6,205	5,837	178	6,015
1951-52:				
Soybeans.....	5,704	5,670	42	5,712
Cottonseed.....	2,524	2,680	35	2,715
Other.....	711	839	9	848
Total.....	8,939	9,189	86	9,275
1956-57:				
Soybean.....	7,510	7,123	443	7,566
Cottonseed.....	2,294	2,250	30	2,280
Other.....	752	711	58	769
Total.....	10,556	10,084	531	10,615
1961-62:				
Soybean.....	10,342	9,262	1,064	10,326
Cottonseed.....	2,629	2,652	26	2,678
Other.....	516	522	28	550
Total.....	13,487	12,436	1,118	13,554
1966-67:				
Soybean.....	13,434	10,771	2,657	13,428
Cottonseed.....	1,744	1,755	7	1,762
Other.....	433	432	93	525
Total.....	15,711	12,958	2,757	15,715

[1] Primarily used as feed. Includes minor quantities of soybean meal used for food and industrial purposes and cottonseed meal used for fertilizer.

Source: (13, table 19; 14, tables 66, 67, 82).

of the less advanced feeding practices abroad.

The domestic feed market for soybean meal had an average annual growth rate of 3.1 percent from 1961-62 to 1966-67 and 4.2 percent from 1956-57 to 1966-67. These are considerably below the growth rates for soybean meal production. The growth rate for soybean meal use in domestic feed is expected to continue to decline, as competition from synthetic urea will remain strong. Contributing to this decline may be other new developments which supply the protein and/or amino acids necessary in a feed from other sources such as other nonprotein nitrogen compounds, synthetic amino acids, high-lysine corn, bacteria, algae, yeast, and mold.

Oilseed meals vary widely in their protein content. For example, regular soybean meal is sold on a 44 percent protein basis, while sunflowerseed cake contains only

about 20 percent protein. To increase the protein content and palatability of oilseed meals, the seed hull is either all or partially removed to produce 50 percent protein soybean meal and 40 to 46 percent protein sunflower meal.

In addition to the various oilseed meals, other natural sources of protein, including several byproduct materials, compete with oilseed meal for use in mixed feeds. Some of these other natural protein sources are fish meal, meat meal, tankage, corn gluten meal, and dried grains from brewers and distillers.

There is considerable substitution among various sources of high-protein ingredients, depending upon price and availability. However, the interchangeability of these protein ingredients is limited because of nutritional factors, such as differences in protein content, amino acid makeup of the protein, fiber content, etc., which are important in livestock feeding. Also, physical characteristics of protein source materials limit their interchangeability.

In the next decade, a large portion of the market for oilseed meal in ruminant rations in the United States may be taken over by urea or other nonprotein nitrogen compounds. However, the overall demand for oilseed meal is expected to hold up well because of the expanding demand for livestock products in the United States and the increased demand for protein meal in overseas markets to feed livestock as well as for use in human diets.

If future competition from synthetic materials should cause the prices of oilseed meals to be reduced, then those oilseeds in which the meal accounts for a high percentage of the total value, such as soybeans, will be affected more adversely. Those oilseeds where the oil makes up a high percentage of the total value will be less affected.

In recent years, oilseed meal has been relatively high priced due to the strong demand for its use in feeds. Cattle prices at times during recent years have been relatively low. This kind of feed-livestock price relationship tends to stimulate the search for and use of more economical feed ingredients. Because synthetic substitutes for natural feed protein are industrial products, production costs are based primarily on the manufacturer's scale of output and of investment in technological research. When these new types of ingredients are developed and become widely acceptable to the feeder, markets for relatively high-priced ingredients may be lost. High prices for oilseed meal, therefore, speed these developments to the breakthrough stage, which may then be irreversible.

Food Use

The food use of oilseed meal, which is primarily soybean meal, and the possible substitution of oilseed meal protein for animal protein in human diets is discussed elsewhere in this report and therefore will not be dealt with here.

Feed Use

Oilseed meals are predominantly used as high-protein ingredients in animal feeds. However, some oilseed meals are used industrially and in recent years much attention and research are being focused on using oilseed meal for edible purposes. Competition from synthetic materials has only come about in recent years. The most important competition to oilseed meal at present is urea for use in ruminant feeds. Some people feel that it is only a matter of time until nonprotein nitrogen (urea and other materials) will replace oilseed meal in ruminant rations and that oilseed meal will find more use as human food.

Urea

Urea, a nonprotein source of nitrogen, is an organic chemical discovered in 1773 and first synthesized in 1828. It was first demonstrated that sheep could utilize it in 1918. Urea replaces protein meal from natural sources in two basic ways: (1) by direct use in mixed feeds, and (2) by use as fertilizer to increase the yield and the protein content of grass and forage crops.

Direct feeding of urea is limited to ruminant animals--cattle, sheep, and goats. Usually, young ruminant animals should not be fed urea. In most States, urea use in feeds is regulated under State feed control laws. The Association of American Feed Control Officials, Inc., has published the following rule regarding use of urea and other nonprotein materials in rations of ruminant animals:

> If the commercial feed contains more than 8.75% of equivalent crude protein from all forms of nonprotein nitrogen, added as such, or if the equivalent crude protein from all

forms of nonprotein nitrogen, added as such, exceeds one-third of the total crude protein, the label shall bear adequate directions for the safe use of such feeds and the statement: "CAUTION: Use as directed."

Although this rule has not become law in all States, it does represent the official policy of this Association. In the United States, urea competes to varying degrees with cottonseed meal, soybean meal, and other protein ingredients for use in feeds.

In the rumen of animals the nitrogen from urea is coverted into usable proteins by microorganisms. These bacteria are then digested by the ruminant host, thus supplying protein to body tissues. Urea contains no energy, therefore, carbohydrates (grains, molasses, etc.) are required to supply energy to the bacteria which break down the urea.

One pound of urea plus 6 pounds of corn can substitute for 7 or 8 pounds of oilseed meal. Experiments have shown that in high grain rations, urea may be fed safely to supply all the supplemental protein. The rate of gain on high urea rations has never quite equaled that on natural protein. Urea is not used for improved performance but for lower cost of production of livestock or livestock products (19).

Fertilizer urea has a nitrogen content of about 46 percent. Feed-grade urea, due to additives to prevent caking and improved mixing qualities, is now 45 percent protein. However, fertilizer-grade urea has been used successfully in feeds. Urea is not safe for feeding unless the rate of use is rigidly controlled. A lump or concentrated mass of urea eaten by an animal can be toxic or fatal. Knowledge of how to use urea safely, improved packaging to help prevent caking, and improved feed mixing and feeding equipment have been instrumental in increasing the use of urea in feeds.

The present and expected major use of urea is as a fertilizer in both domestic and in foreign markets. When urea is applied to pasture and forage crops, it stimulates production and increases the quality (raises protein level) of the pastures and harvested forage crops. In using urea in this manner there are no toxicity problems and no costs of mixing or feeding with grains. Using urea fertilizer, yields of some grasses can be increased as much as fivefold and protein content doubled. The increased use of urea as a fertilizer may cause a decrease in the feeding of concentrates to ruminants; therefore, urea fertilizer could have a larger impact on oilseed meal consumption than use of urea in direct feeding, but this is not likely. How fast the practice of applying urea to pasture and forage crops will take place and the impact it will have on oilseed meal consumption are difficult to predict. This is dependent upon the decisions of many individual farmers on how quickly they adopt this type of urea fertilizer use and how widespread a practice it becomes.

The use of urea as a source of protein in cattle feeds has expanded rapidly in recent years. The primary reason has been that it provides protein at a lower cost than oilseed meals. Farmers have been able to make significant savings by using a urea-grain mixture in place of more costly natural high-protein feed ingredients. Urea use in feeds is expected to continue growing and could ultimately reach the ceilings on use mentioned earlier if economics are favorable.

Scientists are searching for ways in which urea can be made more palatable and can be fed to ruminant animals at rates higher than those presently considered safe. Researchers at Kansas State University have reported development of a starch-controlled urea product called "Starea," which they claim can overcome many problems associated with feeding urea or other nonprotein nitrogen compounds to ruminant animals. Urea or other nonprotein nitrogen compounds are mixed with finely ground grain (corn, milo, barley, or other grains) and then processed through a cooker-extruder which causes the starch material to gelatinize (23). This material offers potential savings in ruminant feeding through greater replacement of oilseed meals with urea or other nonprotein nitrogen compounds than was previously possible.

Approximately 30 firms now manufacture urea in the United States. In 1966, sales of urea in the United States totaled 1,632,000 tons (see table 11). Use of urea in 1966 was as follows: Feed, 11.8 percent; fertilizer, 81.5 percent; and plastics and other uses, 6.7 percent. The accuracy of this breakdown is questionable since use of urea for feed or fertilizer is so interchangeable that the final use of the product is determined by the user and not the manufacturer. Some estimates place total feed use of urea at about double the sales figure shown for feed-grade use. The growth rate for feed urea, 1962-66, was 13.9 percent per year. However, there was a 32 percent increase in sales of urea in 1966 over 1965 and all use categories contributed substantially to this increase. Urea growth for the next 5 years is estimated at 10 percent per year.

Table 11.--Urea: Distribution of sales from domestic production, selected years[1]

Year	Feed	Fertilizer solid and liquid	Plastics and other industrial	Total
	1,000 tons			
1957.....	65.1	276.0	107.1	448.2
1962.....	114.1	789.3	63.6	967.0
1966[2].....	192.0	1,329.9	109.8	1,631.7

[1] All data are shown on a 46 percent nitrogen basis. Feed urea now contains 45 percent nitrogen--until recent years, it contained 42 percent nitrogen.
[2] Latest year available at time of publication.

Source: (33, table 21A).

Table 12.--High-protein feeds fed to cattle and sheep and sales of feed grade urea, October-September, selected years

Year beginning October	High-protein feed in terms of 44 percent protein soybean meal						
	Oilmeals, animal proteins and grain proteins fed to livestock and poultry					Sales of feed-grade urea[1]	
	Total, all livestock and poultry	Beef cattle	Dairy cattle	Sheep	Total, cattle and sheep	From domestic production[2]	As a percentage of protein fed to cattle and sheep
	1,000 tons	1,000 tons	1,000 tons	1,000 tons	1,000 tons	1,000 tons	Percent
1956.....	13,212	1,789	1,784	189	3,762	382	10.2
1961.....	16,160	2,698	2,282	210	5,190	670	12.9
1965.....	17,504	2,740	2,688	259	5,687	1,127	19.8

[1] Sales of 46 percent nitrogen feed-grade urea from table 12 converted to 42 percent nitrogen basis. Assuming urea is a 262 percent protein feed and 90 percent is directly substituted, a factor of 5.36 is used for converting urea to 44 percent protein soybean meal equivalent.
[2] Year beginning following January.

Source: (31, p. 33). 1965-66 data from Econ. Res. Serv., Econ. and Statis. Anal. Div.

The wholesale price of urea has been stable at about $90 to $100 per ton for the past 5 years. Capacity could outstrip demand in the near future, making for lower prices.

In 1965-66, cattle and sheep consumed natural high-protein material equal to 5,687,000 tons of 44 percent soybean meal (table 12). The average annual growth rate from 1961-62 through 1965-66 was 2.3 percent. Therefore, use of feed-grade urea has increased at a much faster rate than use of natural high-protein materials in the feeding of cattle and sheep.

In addition to the natural high-protein ingredients mentioned above, ruminants in 1966 (latest year available) were fed 192,000 tons of urea, the equivalent of about 1.1 million tons of 44 percent soybean meal.

This is equal to the production of soybean meal from about 1,875,000 acres of soybeans. If urea were fed up to its ceiling (one-third of the protein in ruminant rations), then in 1965-66, 423,000 tons of urea could have been fed; the equivalent of about 2.3 million tons of 44 percent soybean meal. This is equal to the meal produced from about 3,785,000 acres of soybeans. The possible increase in urea use is not as great as the 231,000 tons indicated here because some fertilizer urea is presently being used in feed and also because no information is available to indicate what part of the imported urea is used in feed.

Other Nonprotein Sources of Nitrogen

Experiments are being conducted with feed formulations using newer and more economical sources of nitrogen than that in urea. Ammonia, a more basic source of nitrogen than urea, is reacted with phosphoric acid to form ammonium polyphosphate. University research has already shown that ammoniated phosphorus compounds are satisfactory sources of both nitrogen and available phosphorus (19).

Synthetic Amino Acids

Protein is a term used to describe material composed of amino acids. There are 24 amino acids that are thought to be protein constituents. The number of these amino acids essential to health varies with different animals. Some of the amino acids are synthesized by the animal's body, while others must be supplied by the diet. The chick for optimum growth requires 11 amino acids. Under carefully defined dietary conditions, the quantitative requirements for growth or for nitrogen balance have been established for chickens, pigs, dogs, and rats. The amino acid composition of many feeds and foods is now known. Vegetable proteins, with the exception of some legumes, are inferior in quality to most proteins from animal sources (22).

Several of the essential amino acids in protein can now be synthesized. Synthetic methionine, lysine, and glycine are now being commercially manufactured. Synthetic methionine has been used in feeds for some time, but synthetic lysine was manufactured for the first time in 1967. Synthetic amino acids are a threat to oilseed meal markets in three ways: (1) They reduce the quantity of protein concentrates needed by supplementing the limiting amino acids in the meal, (2) permit use of amino-acid-fortified cheaper concentrates, and (3) permit the use of amino-acid-fortified grains in place of protein concentrates.

Methionine is used to fortify corn-soybean meal poultry feeds at the rate of about 1 pound per ton. In 1961, about 6 million pounds were used in the formulation of domestic poultry feeds (22). By 1965, this had increased to 12 million pounds. In 1953, when synthetic feed-grade methionine was new, it sold for $2.95 per pound. Today, it sells for $1.10 per pound. Innovations of the future could lower costs further. As there is only one producer of feed-grade methionine in the United States, much of our supply is imported (28).

Lysine at the rate of 1 to 2 pounds per ton of a corn-soybean ration for swine has been shown to accelerate growth and improve feed efficiency (22). Lysine has been produced in this country by a fermentation process. The world's first synthetic lysine plant was built in the Netherlands and was scheduled to begin production by the end of 1967. Seventy companies throughout the world have applied for licenses to produce synthetic lysine but the patent-holding company to date has not granted any licenses (3). With the prospect of lower-priced synthetic lysine, considerable quantities of this amino acid might be used in animal feeds.

Earlier, three ways were described in which amino acids would substitute for oilseed protein meals. Up until now, because of the price of oilseed meals and synthetic methionine, only the first of these substitutions has taken place--reduction in the quantity of protein concentrates needed by fortification with synthetic methionine, the first limiting amino acid in poultry rations. Further reductions may take place with the fortification of animal rations with synthetic lysine.

If the cost of protein concentrates should rise very much or the cost of synthetic amino acids become much lower, then the second and third types of substitution--amino-acid-fortified cheaper concentrates and amino-acid-fortified cereal grains--might come into widespread use. At the present time, these appear to be extremely long-range prospects.

High-Lysine Corn

A mutant corn gene carrying higher levels of the important amino acids, lysine and

tryptophan, was discovered at Purdue University by Nelson and Mertz in 1963 (4). The discovery that these amino acids were carried by a single gene is a tremendous breakthrough. It may enable the increase of other amino acids in corn. It also opens the door for the possible improvement in protein and amino acid makeup of other monocotyledons--milo, wheat, barley, rye, oats, etc.

The protein in corn is a relatively minor constituent but it is important in feeding animals and people, especially when corn makes up a large portion of the diet. Some nutritionists estimate that high-lysine corn can replace 50 percent of the soybean meal needed in swine finishing rations (20). High-lysine corn contains about 2.5 percent more protein than regular hybrid corn--11.5 vs. 9.1 percent. Lysine and tryptophan, two essential amino acids, are found in considerably higher amounts in high-lysine corn than in normal corn; lysine 0.49 vs. 0.24 percent and tryptophan 0.15 vs. 0.09 percent (17).

However, there is one major drawback that will prevent high-lysine corn from being grown for feed purposes in the near future, and that is yield per acre. In 1967, high-lysine corn in test plots at the University of Illinois had yields averaging 15 percent less than yields of genetically normal counterparts. The best yielding high-lysine seed produced 92 percent as much as its genetically normal counterpart (16). Researchers are hopeful of increasing high-lysine corn yields. Geneticists estimate it will take several more years to implement commercial production of high-lysine corn (18) and considerably longer to commercially produce high-lysine corn with higher yields.

There are also additional problems in handling and storing high-lysine corn. Currently, high-lysine corn hybrids are much softer than genetically normal corn. This means that kernels may be damaged more easily and are more susceptible to attack by insects and molds. High-lysine corn also contains more moisture at harvest and retains it longer than normal corn, thus making storage more difficult. However, if yield of high-lysine corn can be increased to the yield levels of genetically normal corn then oilseed meals will be in less demand for use in feed.

It appears that high-lysine corn will be of more value as human food than as an animal feed. Corn is the principal food in the protein-deficient diet of many people in Latin America. High-lysine corn may be of significant help in improving the nutrition of these people.

High-lysine corn poses a similar threat to oilseed meal markets in animal feeds that synthetic lysine does. This threat is greatest in swine rations since hogs require a high level of lysine. Due to its higher protein content, high-lysine corn is also of slightly more value than regular corn in poultry and cattle feeds. If high-lysine corn is used in animal feeds, the additional protein would displace oilseed protein materials, mainly soybean meal, and it would probably be at a rate higher than pound-for-pound substitution of protein because lysine is one of the limiting amino acids in swine rations.

Now that the commercial production of synthetic lysine is a reality, it may provide lysine in the near future at a cost less than lysine produced by high-lysine corn. If this occurs, it is doubtful that high-lysine corn will ever be much of a factor in the feed market.

Protein from Petroleum

The possibilities of the commercial production and use of protein obtained from bacteria that are grown on petroleum is discussed elsewhere in this report and, therefore, will not be dealt with here.

Industrial Use

Industrial (nonfood, nonfeed) uses of oilseed meal represent a minor outlet for meal. Soybean meal is the only meal having any significant industrial uses. The principal industrial use of soybean meal protein is in adhesives, some of which are soybean-blood mixtures.

Adhesives

Chemically, adhesives can be divided into two groups, organic and inorganic. The organic adhesives are polymers of high molecular weight. Soybean protein, starch, blood, casein, rubber, asphalt, phenolic, and isocyanate are organic adhesives. The major inorganic adhesives are sodium silicate, gypsum (plaster of paris), and portland cement (calcium silicate-alumina-iron oxide). Adhesives can also be classified as to their origin, natural or synthetic (man-made). Soybean protein, starch, casein, blood, animal glue, asphalt, and natural

rubber are types of natural adhesives. Phenolic, epoxy, sodium silicate, polyvinyl acetate, and isocyanate are examples of synthetic or manmade adhesives.

Estimates of quantities consumed and annual growth rates for recent years on the various raw materials used in the manufacture of adhesives are shown in table 13.

The synthetic resins will continue to be used at an increasing rate because their properties can be tailored better to meet the stringent specifications of the newer adhesive applications.

Starch, the largest volume adhesive, is widely used because it is low in cost ($0.07 per pound in 1967), in plentiful supply, and easy to apply. Starch is the principal adhesive used for bonding and sealing paper products (labels, stamps, tags), corrugated boxes, and tube winding. The good adhesion of starch allows it to be used for many other purposes as in the sizing of paper and textile yarns.

Soybean flour and blood are used in plywood adhesives. They may be the main components or extenders in phenolic resins, or blended with casein or sodium silicate.

Animal glue is one of the more important protein glues. Included in this category are hide and bone glues. Animal glue is used for remoistenable gum tapes and for better quality furniture.

The principal use for casein adhesives is in wood glues, especially indoor structural

Table 13.--Estimated adhesives consumption by chemical type, 1962 and 1967

Adhesive raw materials (dry polymer)	1962	1967	Average annual growth rate
	Mil. lb.	Mil. lb.	Percent
Synthetic resins and rubber:			
Phenolic	315	490	
Amino	210	310	
Rubber (natural and synthetic)	184	266	
Polyvinyl acetate	90	205	
Other vinyl (butyral, formal)	30	49	
Acrylic	15	36	
Polyester	10	25	
Resorcinol	12	19	
Polyurethane	10	24	
Polyvinyl alcohol	12	19	
Epoxy	7	17	
Other	15	31	
Total	910	1,491	10.4
Natural:			
Starch and dextrin	445	575	5.3
Animal glue	110	140	
Casein and soybean	285	326	2.7
Blood	50	53	
Subtotal (farm derived)	890	1,094	4.2
Silicates	165	192	
Asphalt	430	580	
Fillers and extenders	270	345	
Other (natural)	75	116	
Total (total natural)	1,830	2,327	4.9
Total (all adhesives)	2,740	3,818	6.9

Source: Correspondence with B.J. Kotsher, editorial director of Adhesive Age, May 1968.

laminates. Casein is an inexpensive replacement for phenolic resins for interior plywood applications which would not have exposure to high humidity. Casein solutions blended with rubber latex are used for bonding aluminum foil to paper.

Although farm-derived adhesives--especially soya, animal glue, blood, and casein--are cheap (10 to 30 cents a pound in 1967), their markets are limited and in some cases declining, because cost is not always the main consideration in choosing an adhesive for industrial uses. The deciding factors are the cost of the entire adhesive or bonding operation and the capability of meeting production-line speed with a minimum of labor and machinery. Also, for an ever-increasing number of uses, farm-derived adhesives lack quantities that are inherent in various synthetic resins--resistance to environmental conditions, temperature extremes, prolonged stress, water, and various chemicals, and even low electrical conductivity.

Adhesive materials of natural origin have features which will enable them to have high market survival value: Their cost is low; large quantities are available; they are nontoxic, and relatively easy to handle; most of them are applicable with water, are moderately heat resistant, and are remoistenable if desired. However, new modifications of farm-derived adhesive materials will be needed for these materials to have the market acceptance currently enjoyed by some of the synthetic polymer adhesives.

SUMMARY

About 10 billion pounds of fats and oils were used in 1967 in the manufacture of food products--butter, lard, shortening, margarine, cooking and salad oils, mellorine, filled milk, and others. There are relatively few food uses in which synthetic materials substitute for fats and oils, primarily because the Food and Drug Administration has not approved their use. Synthetic food surfactants (surface-active agents) or emulsifiers have been used to some extent, and stand as a major future threat to fats and oils markets in food. The markets, primarily the baking industry, most susceptible to inroads of synthetic or partially synthetic emulsifiers are estimated to consume about 2 billion pounds of fats and oils a year at present.

Industrial uses of fats and oils ranged between 4.8 and 5.4 billion pounds between 1962 and 1967. Soap, formerly one of the largest markets for fats and oils, in 1967 used only 714 million pounds, one-third as much as in 1947, because of the increasing use of synthetic detergents. The 1967 use of drying oils in paint, printing ink, floor covering, and calking compounds was 686 million pounds, only 64 percent of what it was in 1950. The increased use of synthetic detergents, tall oil (a byproduct of the paper industry), synthetic resins, and plastics to replace oils from oilseeds and animal fats is due to either their lower price or better performance.

The largest new domestic market for fats and oils is in animal feeds. In 1967, almost 1 billion pounds of inedible tallow and grease were used for this purpose. More fats are expected to be added to feed because of production of commercial feeds will be larger and a higher share will be pelleted. Mineral oil, although lacking in food value, could possibly displace as much as one-third of the fats and oils used in feeds.

Fatty acid manufacture used more than 700 million pounds of fats and oils in 1967. Tall oil is an increasingly important fatty acid raw material because of its plentiful supply and low price. Tall oil accounted for 62 percent of the fatty acid raw materials in 1967 and tallow about 30 percent. Synthetic fatty acids produced from petroleum are a major threat to this fats and oils market, although present production is small.

Glycerine was originally a byproduct of soap, fatty acid, and fatty alcohol manufacture. Since 1948, glycerine has been commercially available from petrochemical sources, and now synthetic glycerine constitutes about 60 percent of the total supply. Most of the future growth of glycerine production will be from petrochemical sources.

The production of oilseed meals in 1966-67 was 16 million tons, a 50 percent increase over production in 1956-57. Almost all this growth was in soybean meal. Meal exports increased sixfold in the same period, to about 3 million tons. In the next few years, domestic and export demand for soybean meal for use in feed is expected to increase. Industrial uses of oilseed meal are small and are expected to remain small.

Oilseed meals are being increasingly displaced by urea and other nonprotein nitrogen materials. These materials will continue to displace more oilseed meal in ruminant feeds because they provide protein at a lower cost than oilseed meals. In 1966,

ruminants were fed 192,000 tons of urea, equivalent to 1,126,000 tons of soybean meal. These synthetics, as well as synthetic amino acids, high-lysine corn, and protein from petroleum, may provide more competition to oilseed meal. Synthetic amino acids are presently being used to supplement amino acids in oilseed meal, thus reducing the quantity of protein needed. In the future, if the price of oilseed meal should rise or the price of synthetic amino acids decline, then cheaper concentrates and grain fortified with synthetic amino acids could displace additional quantities of oilseed meal. If yields of high-lysine corn can be increased to the yield levels of presently grown corn, then oilseed meals will be in less demand for use in feeds.

BIBLIOGRAPHY

(1) Chemical and Engineering News
1968. End of Glycerine Shortage May Be on Way. Mar. 4.

(2) Chemical and Engineering News
1967. Glycerine Supplies Remain Tight. July 31.

(3) Chemical Week
1967. Miner Strikes It Rich in Laboratory. Oct. 14.

(4) Corn Industries Research Foundation
1966. Proceedings of the High Lysine Corn Conference. June 21-22.

(5) Doty, Harry O., Jr.
1953. Detergents, Emulsifiers and Emulsion Products as Market Outlets for Fats and Oils. Part II: Emulsifiers and Emulsion Products. U.S. Dept. Agr., Mktg. Res. Rpt. 46.

(6) _____
1961. Fats Added to Feeds, An Economic Analysis. U.S. Dept. Agr., Mkt. Res. Rpt. 498.

(7) _____
1958. Fats and Oils Consumption in Prepared Animal Feeds. U.S. Dept. Agr., Mkt. Serv., AMS-252.

(8) Ellinger, R. H., and Hoerr, C. W.
1963. Challenge of the Baking Industry. Jour. Amer. Oil Chem. Soc., June.

(9) Economic Research Service
1967. Fats and Oils Situation, U.S. Dept. Agr., FOS 237. April.

(10) Economic Research Service
1967. Fats and Oils Situation, U.S. Dept. Agr., FOS 238. June.

(11) _____
1968. Fats and Oils Situation, U.S. Dept. Agr., FOS 241. Jan.

(12) _____
1968. Fats and Oils Situation, U.S. Dept. Agr., FOS-242. April.

(13) _____
1967. Feed Situation. U.S. Dept. Agr., FDS-221. Nov.

(14) _____
1967. Feed Statistics Through 1966. U.S. Dept. Agr., Statis. Bul. 410.

(15) _____
1966. U.S. Fats and Oils Statistics, 1909-65. U.S. Dept. Agr., Statis. Bul. 376.

(16) Feedstuffs
1967. High Lysine Corn. Aug. 26.

(17) _____
1966. Opaque-2 Corn Superior. Sept. 3.

(18) _____
1968. New Corn Still 3-5 Years Away. Apr. 27.

(19) _____
1968. Scientists Present Information on NPN, Molasses, Liquid Supplements for Beef Cattle. Mar. 30.

(20) _____
1968. Swine Research, Competition for Pork Industry. Paper presented at Univ. Ill., Apr. 27.

(21) Hester, O. C. and Boggs, R. L.
1964. Market Potential for Modified Edible Fats and Oils. U.S. Dept. Agr., Mktg. Res. Rpt. 659.

(22) Howe, Eugene E.
1962. The Role of Amino Acids in Nutrition. Chem. & Engin. News, July 23.

(23) Kansas Agricultural Experiment Station
1968. A New Urea Product for Ruminants. Feedstuffs, Apr. 27.

(24) Kline, Charles H.
1965. Marketing Guide to the Paint Industry. Charles H. Kline & Co., Pompton Plains, N.J. (See also Annual Review, 1966 and 1967.)

(25) Kromer, George W.
1967. Fatty Acids: An Expanding Market for Fats and Oils. U.S. Dept. Agr., Econ. Res. Serv., ERS-345.

(26) _____
1967. Glycerine: Demand Strong for Limited Supplies. U.S. Dept. Agr., Econ. Res. Serv., ERS-328.

(27) Moffett, J. C., Jr., and DeAcetis, W.
1968. Synthetic Fatty Alcohol and Acids--New Additions to the Raw Material Pool for Soaps and Detergents. Paper presented at Amer. Oil Chem. Soc. Spring Mtg.

(28) Oil, Paint, and Drug Reporter
1966. Methionine: Feed-Grade World Sales Nearing to 20 Million-Pounds Mark. May 13.

(29) _____
1968. Surfactants for Foods: Steady Growth is Seen. Apr. 8.

(30) Pattison, E. Scott
1968. Fatty Acids and Their Industrial Applications. Marcel Dekker, Inc., New York, N.Y.

(31) Ross, Jack S.
1964. Urea Expands as a Source of Protein Feed in Recent Years. U.S. Dept. Agr., Feed Situation, FDS-205, August.

(32) Speel, H. C. and Poats, F. J.
1964. Economic Potential of Soaps, Detergents, and Surfactants Made from Fats and Oils. U.S. Dept. Agr., Agr. Econ. Rpt. 53.

(33) U.S. Tariff Commission
1957. Synthetic Organic Chemicals: U.S. Production and Sales. (See also annual reports, 1962 and 1966.)

(34) Zabel, Herman W.
1967. Glycerine Outlook. Paper presented at the Soap and Detergent Assoc. Conv. Jan. 25.

(35) Zilch, Karl C.
1968. Synthetic Fatty Acids in Eastern Europe. Jour. Amer. Oil Chem. Soc. Jan.

Protein from Petroleum

By Ray S. Corkern

CURRENT SITUATION

Only limited information is available on the various processes for converting petroleum into protein by biochemical means. These processes differ only in the petroleum fraction used in the nutrient medium and in the type of organisms used. One petroleum company uses an organism that utilizes a long-chain paraffin in a heavy oil fraction; an oil company uses a bacterial strain that oxidizes methane. The Institute of Gas Technology is studying a similar technique, and another oil company uses a process in which a microorganism is grown on a normal alkane medium (3, 5, 10).[1] The diversity of these research approaches emphasizes (1) the importance the petroleum industry is placing on the conversion of hydrocarbon into protein, (2) the continuing search for an economic and technically sound process that can be used in commercial production, and (3) the diversity of organisms that can subsist on hydrocarbon.

The second, third, and fourth steps along the route to commercialization are being pursued. The second step is pilot scale production, the third step is actual trial feedings to determine whether or not toxic effects can be expected, and the fourth is the use of petroleum protein in human food.

A pilot scale production plant has been reported in the United States (3, 13). In Europe, two pilot plants are in operation; one is producing over 200 pounds of protein daily. Reports have been published that the capacity of one of these plants will be increased to 16,000 long tons per year (4). The company operating the pilot plants in Europe is planning a pilot plant in Nigeria (5). Reports also have been published that Russia has a 15-ton-per-day plant in operation (6). A Japanese firm is planning a 60,000-ton-per-year plant to produce a feedstuff containing 60 percent protein. Completion is expected early in 1970 (9). Taiwan, Mainland China, and Austria are experimenting to discover the potential of petroleum as a source of edible yeast (7, 11).

A petroleum company reports that in Europe trial feedings with small animals have been successful. These feedings were conducted with mice, rats, quails, chickens, and pigs (8). A domestic oil company conducted trial feedings with mice and rats, but no results were reported.

Petroleum-derived protein has been put into foods (1). Experiments have been made with meat concentrates and fermented fish sauces to evaluate the feasibility of incorporating protein supplements into food. These test foods were not consumed by humans. Developments in the conversion of petroleum into protein have gained recognition, but use of petroleum-derived protein in food products will become a reality only after further research and expenditure of money.

THE SYNTHESIS OF PROTEIN FROM PETROLEUM

The technique of producing yeast and other single-cell organisms for protein concentrates, vitamins, and amino acids by the fermentation process, using sugar or carbohydrates as the principal nutrient, is a well-established commercial process in the United States. The same technique has been employed in pilot plants in Europe, but petroleum has been used as the principal nutrient. A decade ago USDA's Northern Utilization Research and Development Division, Peoria, Ill., employed a similar technique for synthesizing vitamin A by use of kerosene and steep liquor.

In the petroleum industry, crude oils are fractionated into their component parts. One necessary step in the fractionation process is the removal of crude waxes. In pilot plants in Europe microorganisms are utilized to dewax high paraffinic gas oils. Since protein is the byproduct, it is natural to look to feed and food outlets for a market.

Underscored numbers in parentheses refer to the Bibliography, p. 85.

Raw Material Requirements

The raw materials used to produce yeast from petroleum are similar to those used to grow yeast on sugars, except that sugar is replaced by a gas oil fraction as the principal nutrient. Other raw materials added to the growth medium are nitrogen from ammonium salts, phosphorus, potassium and magnesium salts such as those found in common fertilizer form, trace elements, vitamins, water, and air. The most important raw material is the seeding organism. Organisms vary in their ability to convert hydrocarbons into proteins, and different species produce protein with different amino acid compositions.

Processing Steps (2)

The processing steps in the petroleum conversion technique are (1) preparation of the growth medium, (2) seeding the fermentation tank with aerobic organisms, (3) aeration and agitation of the growth medium, (4) centrifugal separation, (5) washing, and (6) drying. These steps would comprise only one phase of multiunit operations involved in processing petroleum products and, to be successful, must be coordinated with all other processing phases.

Some Possible Technical Problems

The transition from semicommercial protein production to large-scale production may give rise to several engineering problems. The first is the insolubility of hydrocarbons in water. Oily hydrocarbons can be mixed in watery mediums in suspension only. Thus, to keep the hydrocarbon droplets well dispersed through the medium, vigorous and continuous stirring will be required. In a large-scale production unit, this is rather difficult. The second problem concerns aeration. Air must be continuously pumped through the medium when hydrocarbons rather than sugars are the principal component of the substrate. Approximately three times as much air is required in the petroleum process. The second problem gives rise to a third. As air is pumped through the medium, the output of heat by the growing cells increases. This will require the installation of a cooling system that can maintain temperature within a narrow range.

Yields of Yeast Grown on Petroleum Substrates

Several variables affect the yield of yeast from petroleum substrates. The first is the wax content of the gas oil fraction. It has been estimated that under ideal conditions the yield of yeast is equivalent to the wax content of the substrate. For example, 100 tons of a crude oil with a 10 percent paraffin wax content would yield 10 tons of yeast consisting of 45 to 50 percent protein (4). By comparison, the yield of single-cell protein from 10 tons of a carbohydrate substrate would be only 5 tons (14).

The second variable is the species of organism used to convert the hydrocarbons. Organisms vary in their ability to utilize hydrocarbons as a source of nutrients. Also, the amino acid composition of protein produced by the various species of organisms varies.

The third variable affecting yields is the operating conditions maintained throughout the entire process, such as aeration, pressure, temperature control, and composition of the nutrient medium. If any one of these are not optimum for a specific species of organism, the yield of protein will be reduced.

PROTEIN FROM PETROLEUM AND PROTEIN FROM SELECTED FOODSTUFFS

The general composition of the protein-vitamin concentrate obtained in European experimental laboratories is shown in table 1.

Table 1.--General composition of protein-vitamin concentrate

Component	Percentage of total composition
Moisture	7.03
Total nitrogen	6.92
Lipids	18.50
Carbohydrates	21.90
Protein (N x 6.3)	43.60
Ash	4.43
Calcium	.21
Phosphorus	1.25
Potassium	.50

Source: (2).

The amino acid composition of protein from several sources is presented in table 2. The amino acid composition of protein from petroleum products can be expected to vary if organisms other than those used in the European experiments are used. Wheat flour is generally considered low in lysine, and the other protein sources in table 2 are low in either cystine or methionine. Since the protein from petroleum is also low in cystine and methionine and cereal grains are generally sufficient in these two amino acids, some combination of cereals and petroleum-protein supplements would need to be made to obtain an adequate balance of amino acids in human food and animal feeds. Foods and feeds with an adequate balance of amino acids can be developed from agricultural products with the addition of presently available synthetic amino acids. Thus, it seems that petroleum proteins will in the near future become a supplementary source of protein for animal feeds rather than a complete replacement of oilseed meal protein materials.

MARKETS AND ECONOMICS

The world protein deficit has been well documented. Any new protein product that becomes technically and economically feasible will contribute partially to the solution of the worldwide food and feed problem. However, extensive market development is usually required to overcome consumer bias toward new products. This has been most evident in those countries that have the largest protein deficits. The marketing of protein from petroleum will be no exception.

The first market envisaged for protein from petroleum is the ruminant and nonruminant animal feed industry. In this market, feeds from petroleum protein must be able to compete on a price basis with protein feeds such as soybean meal, meat meal, urea, and fish meals. Since petroleum protein also does not have an adequate amino acid balance, it may be necessary to use it in combination with some other protein source or primarily as a source of vitamins. In the first instance, petroleum protein will become a partial replacement for agricultural protein and in the second it will compete with available synthetic vitamin concentrates.

Reported cost of production is near $120 per ton of dry cells containing 35 percent protein. This cost estimate is based on a plant producing 500 tons per day, 90 percent utilization, 1963 French price levels, and without a charge for taxes (2). In the

Table 2.--Amino acid content in 100 grams of protein from petroleum and selected materials

Amino acid	Soybean meal, 61.4 percent protein[1]	Beef[2]	Cow's milk[2]	Wheat flour[2]	Torula yeast[2]	Petroleum protein-vitamin concentrates[2 3]
			-Grams-			
Leucine	7.7	8.0	11.0	7.0	7.6	7.0
Isoleucine	5.1	6.0	7.8	4.2	5.5	3.1
Valine	5.4	5.5	7.1	4.1	6.0	8.4
Threonine	4.3	5.0	4.7	2.7	5.4	9.1
Methionine	1.6	3.2	3.2	1.5	.8	1.2
Cystine	1.6	1.2	1.0	1.9	1.0	.1
Lysine	6.9	10.0	8.7	1.9	6.8	11.6
Arginine	8.4	7.7	4.2	4.2	4.1	8.0
Histidine	2.6	3.3	2.6	2.2	1.7	8.1
Phenylalanine	5.0	5.0	5.5	5.5	3.9	7.9
Tryptophan	1.3	1.4	1.5	.8	1.6	1.2

[1] Source: (12).
[2] Source: (2).
[3] The method used to calculate the amount of amino acid in the protein-vitamin concentrate was not reported.

United States, estimates of the price per pound of pure protein would be about 35 cents (3). Assuming these estimates are correct then petroleum protein would replace very little of the low-cost oilseed meal protein feeds available in the United States. To become price competitive in the United States, further reductions in production costs must be made. As producers gain experience, production costs may be reduced. However, since one purpose of using organisms on hydrocarbons is dewaxing to upgrade petroleum products, protein production must compete on a cost basis with other dewaxing procedures. At the present time, the paraffinic wax utilized by organisms is also used to produce microcrystalline wax that has a refined price of 10 to 12 cents per pound. Thus, petroleum protein must also compete with microcrystalline wax.

Petroleum protein may be used in food protein supplement. For this use to be realized, an extensive nutritional, toxicity, acceptance, and consumer education program must be undertaken. Recent experiences of companies producing vegetable protein supplements give this statement added weight. Therefore, it is expected that in the immediate future, petroleum protein will not make appreciable inroads into food markets.

The above observations are based on limited information concerning the cost of petroleum protein relative to available vegetable protein. The immediate impact on domestic oilseed meal markets will be limited until costs for producing protein are reduced. Another long-term aspect of this problem involves the use of petroleum resources. Petroleum resources are not unlimited and these crude oils may be highly variable in their paraffinic content. The rising world demand for petroleum products will put added pressures on the available supply of crude petroleum and the products that can be derived from them.

SUMMARY

The use of single-cell organisms to synthesize protein from petroleum fractions is technically feasible. Pilot scale production and trial feedings have been accomplished in the United States and several foreign countries. The first market visualized for protein from petroleum is the animal feed industry. In this market, protein from petroleum must compete on a cost basis with protein from agricultural products such as soybean meals. The impact of the production of protein from petroleum on domestic oilseed meal markets will be limited until production costs are reduced and extensive toxicity testing has been completed.

BIBLIOGRAPHY

(1) Champagnat, Alred.
1965. Protein from Petroleum. Scientific American, vol. 213, no. 4, Oct.

(2) _____, Berret, Charles, Laine, B., and Filosa, J.
1963. Microbiological Dewaxing Process Yielding Protein-Vitamin Concentrates. Neftekhimiya, vol. 3, no. 5.

(3) Chemical and Engineering News.
1967. Chemical and Engin. News 45(2): 46-48.

(4) _____
1967. Chemical and Engin. News, vol. 45, no. 50, Nov.

(5) _____
1967. Chemical and Engin. News 74(25): 82-83.

(6) Chemical Week.
1968. Chemical Week, vol. 102, no. 9, Mar.

(7) _____
Chemical Week, vol. 102, no. 1, Jan.

(8) Feedstuff.
1967. Feedstuff 39(48): 2, 69.

(9) Oil, Paint and Drug Reporter.
1967. Oil, Paint and Drug Rptr. 193(24): 1.

(10) _____
1967. Oil, Paint and Drug Rptr., vol. 191, no. 7, Feb.

(11) Perlman, David.
1967. Fermentation Industry Brews a Formula for Global Competition. Chemical Week, vol. 101, no. 25, Dec.

(12) Rackis, J. J., Anderson, R. L., Sasame, H. A., and Smith, A. K.
1961. Amino Acids in Sorghum Hulls and Oil Meal Fractions. Agricultural and Food Chem., vol. 9, no. 5, Sept-Oct.

(13) Wall Street Journal.
1967. Wall Street Jour. 39(112): 1, 11.

(14) White House Office
1967. The World Food Problem: A Report of the President's Science Advisory Committee, vol. 2, p. 362. U.S. Govt. Printing Off., Washington, D.C., May.

U. S. GOVERNMENT PRINTING OFFICE : 1969—394-374/ERS-20

UNITED STATES DEPARTMENT OF AGRICULTURE
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